

Regular Meeting

Wednesday, June 11, 2014 7:00 PM

Auditorium, 129 Church Street, Bristol, CT 06010

1. Call to Order, Pledge of Allegiance, Moment of Silence

2. 2015 Bristol Teacher of the Year **Presenter:** Ellen Solek

3. Approval of Minutes

4. Committee Reports

5. Superintendent Report

- 5.1. Whitson's Presentation **Presenter:** Whitson's Representative

- 5.2. Safety of Student Athletes Report **Presenter:** Chris Cassin

- 5.3. Full Day Kindergarten

- 5.4. Safety and Security Update

6. Consent Agenda

6.1. Personnel

- 6.1.a. Administrator Retirement - Effective June 30, 2014

- 6.1.b. Administrator Hires - Effective July 1, 2014

- 6.1.c. Teacher Retirements - Effective June 30, 2014

- 6.1.d. Teacher Resignations - Effective June 30, 2014

- 6.1.e. A-2 Teacher Resignation - Effective June 30, 2014

- 6.1.f. A-3 Teacher Resignation - Effective June 30, 2014

- 6.1.g. A-3 Teacher Appointment

- 6.1.h. Coaching Resignations

6.2. Grants

- 6.2.a. Grants from the Stocker Foundation and the Bristol Business Education Foundation

- 6.2.b. Grant from Dollar General for Bristol Adult Education Center

- 6.2.c. IDEA Section 611

- 6.2.d. IDEA Section 619

7. Public Comment

8. Deliberated Items/District Leadership Team Reports

8.1. Bristol Eastern - Italy Trip - June 2015	Presenter: Pam Brisson and Andrew Schacht
8.2. Healthy Food Certification Statement	Presenter: Sue Moreau
8.3. TEAM Mentors/Cooperating Teachers Applicants	Presenter: Denise Carabetta
9. Policy Revision	
9.1. Policy 5113 - Excused Absences - Second Reading	Presenter: Sue Moreau
9.2. Policy 6145-2 Extra-Curricular and Co- Curricular activities - First Reading	Presenter: Chris Cassin
10. Curriculum Revision	
10.1. AP Physics C Curriculum - Second Reading	Presenter: Richard Gagliardi
10.2. AP Physics I Curriculum - Second Reading	Presenter: Richard Gagliardi
10.3. Computer Programming and Video Games Design Curriculum - Second Reading	Presenter: Richard Gagliardi
10.4. Environmental Science Curriculum - Second Reading	Presenter: Richard Gagliardi
10.5. French III Curriculum - Second Reading	Presenter: Pam Brisson
10.6. Spanish IV Curriculum - Second Reading	Presenter: Pam Brisson
10.7. Pre-Calculus Curriculum - Second Reading	Presenter: Lisa Bernabe
11. Textbook Adoption	
11.1. AP Biology Textbook Adoption - Second Reading	Presenter: Richard Gagliardi
11.2. AP Chemistry Textbook - Second Reading	Presenter: Richard Gagliardi
11.3. AP Physics C Textbook Adoption - First Reading	Presenter: Richard Gagliardi
11.4. AP Physics I Textbook Adoption - First Reading	Presenter: Richard Gagliardi
11.5. Environmental Science Textbook Adoption - First Reading	Presenter: Richard Gagliardi
11.6. The Ultimate Guide to Video Game Writing and Design - First Reading *	Presenter: Richard Gagliardi
11.7. French III Textbook Adoption - First Reading	Presenter: Pam Brisson
11.8. Spanish IV Textbook Adoption - First Reading	Presenter: Pam Brisson
11.9. Middle School Mathematics Textbook Adoption - First Reading	Presenter: Lisa Bernabe
12. Old Business	
13. New Business	
14. Information	
15. VOTE TO CONVENE INTO EXECUTIVE SESSION for the purpose of discussing:	
16. Reconvene Into Public Session	

17. Adjournment

BOARD OF EDUCATION
Bristol, Connecticut
SPECIAL BOARD OF EDUCATION MEETING
Thursday, May 22, 2014

A special meeting of the Bristol Board of Education was held on Thursday, May 22, 2014 at 6:25 p.m. at the Board of Education Administration Building, 129 Church Street, Bristol, Connecticut in the Auditorium.

Present: Commissioners: Lawrence Amara, Genard Dolan, Jill Fitzgerald, Karen Hintz, Jeffrey Morgan, Karen Vibert and Christopher Wilson. **Also present:** Dr. Ellen Solek, Superintendent of Schools; Dr. Susan Kalt Moreau, Deputy Superintendent of Schools; Dennis Bieu, Director of Human Resources, Kim Hapken, Director of Special Services and Gary Franzi, Supervisor of Budgeting & Accounting.

Excused: Commissioners: Jennifer Dube and Thomas O'Brien.

1. Call to order

The meeting was called to order at 6:30 p.m.

2. Vote for BPS Walking School Bus

It was **unanimously** voted: ***To adopt the Walking School Bus as a Board of Education sanctioned activity.***

3. Adjournment

With no other business to come before the committee, the meeting was adjourned (6:40 p.m.)

Respectfully Submitted,

Susan Everett

Susan Everett

Secretary Board of Education

**BOARD OF EDUCATION
Bristol, Connecticut
May 7, 2014 – Regular Meeting**

The regular monthly meeting of the Bristol Board of Education was held on Wednesday, May 7, 2014 at 7:00 p.m., at the Board of Education Administration Building, located at 129 Church Street, Bristol, Connecticut.

PRESENT: Commissioners: Jennifer Dube, Genard Dolan, Jill Fitzgerald, Karen Hintz, Jeffrey Morgan, Karen Vibert, Thomas O'Brien, and Chairman Lawrence Amara; Ellen W. Solek, Superintendent of Schools, Susan Moreau, Deputy Superintendent, Dennis Bieu, Director of Human Resources and Henri Martin, City Council Liaison

EXCUSED: Commissioner Christopher Wilson

CALL TO ORDER, PLEDGE OF ALLEGIANCE, NATIONAL ANTHEM, MOMENT OF SILENCE
Chairman Amara called the meeting to order at 7:06 p.m. and invited the audience to join him in reciting the Pledge of Allegiance and The National Anthem.

The Nation Anthem was performed by the Harmonizers:

Madeline Archangelo, Luke Ashworth, Olivia Beaudoin, DeQwon Bentley, Madison Bernier, Nathaniel Carothers, Katie Curtis, Kyle Cyr, Mia Dorantes, Madison Dunn, Zanaii Hickey, Victoria Janelle, Kellen Joseph, Emily Jusino, Aubrey Kelley, Pat Kjornrattanawanich, Paul Kjornrattanawanich, Elizabeth Koval, Tyler Lamoureux, Jason Lipscomb, Lena Losacano, Julianna Marsh, Trevor Mays, Maura McCormick, Ashlie Moderacki, Julia Nelson, Tahlia Ramos, Madeline Rodriguez, Connor Sergeant, Hannah Shapland, Hayley Smith, Kaja Stanecki, Emma Tavera, Isabella Tedesco, Kaleb Whitman, Shy-Ann Whitten, Rachel Wolf, Iryna Zyma.

STAFF AND STUDENT RECOGNITION

Regional and All State Music Ensemble Student Recognition

Angela Lomaglio presented the musical achievements of our students and faculty. Scientific study after study shows that students who take music increase their ability to think-outside-the-box, better deal with social issues, have more self-discipline, score higher on SAT, and are more likely to become student leaders. We are proud of the many students who have been recognized as the top singers and players in the state. Middle School and High School musicians have auditioned with thousands of others to participate in All-State and Regional Bands, Choirs, and Jazz Band. The board acknowledged the following students:

Chippens Hill Middle School

Chorus: Madeline Archangelo, Olivia Beaudoin, Kellen Joseph, Pat Kjornrattanawanich, Aubrey Kelley, Hannah Shapland

Northeast Middle School

Chorus: Juan Calderon, Dylan Cushing, Marisa Drzewiecki, Jalen Drzewiecki, Amari Floyd, Anna Korpanty, Emily Gdovin
Band: Erin Girard, Sean Sullivan, Jade Udoh
Orchestra: Kara Friedman

Green Hills Middle School

Choir: Nathan Suarez (also performed at the 2nd Annual Hotchkiss Music Festival under the direction of Chris Shepard)

West Bristol Middle School

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Band: Taylor Brunet, Dorsye Cantarero (Dorsye sat 1st chair, earned a perfect score on her audition)

Bristol Eastern High School

Chorus: Ashlyn LaVallee

Band: Brenda Krosnicki, Alex Marsh, Caroline Boyce (All-State Band, and CAS Award recipient)

Jazz Band: Caroline Boyce (highest score for Tenor Sax)

Bristol Central High School

Band: Nicole Tabak, Simon Andrews, Benjamin Marcil

Orchestra: Maria Sato, Philip Andrews (All-State Band)

Chorus: Angela Garcia-Clark, Molly Watstein

CAS Award Recipient: Trystan Brunet

Several students were present in the audience and received a congratulatory certificate from Dr. Solek.

Mrs. Lamaglio also shared some highlights of our ensembles that have performed in competition and festivals throughout the city, state and around the country showing Bristol in a great light. Some of the biggest highlights include:

Bristol Eastern's Marching Band won best high school marching ensemble for the 2014 New Haven St. Patrick's Day Parade, and they were one of only 4 bands chosen for the UConn Huskies NCAA Basketball Dual National Championship Parade.

Bristol Eastern's Strawberry Fields acapella choir won first place in the co-ed category, and 4th over-all at Kingswood-Oxford Invitational Acapella Competition, and they were 2nd runner-up at the International Championship of High School A Cappella New England Semifinal.

Our teachers not only give our students the highest level of teaching but they continue to develop professionally as well:

John Abucewicz was selected to be the guest conductor at the "8th Grade Band Day" hosted by the American School Band Director's Association.

Michael Coderre sang at Avery Fisher Hall in the Lincoln Center, as a member of the choir Gaudeamus with other invited choirs under the direction of Eric Whitacre and Stephen Schwartz.

As the National Vice President of Communication and Recognition for the band honor sorority (Tau Beta Sigma), Amy Dauphinais has presented workshops at regional band conferences in Chicago, San Antonio, Dayton, Georgia, and the University of Connecticut. She was also chosen as one of 3 conductors for the Hartford Opera Theater's annual New in November series.

Dr. Solek thanked and congratulated tonight's performers and award recipients for sharing their talents with the Board of Education. We have been fortunate to enjoy several performances throughout the year and we have enjoyed each and every one of them.

Bristol Central - FBLA State Leadership Conference and Competition

Student members of the FBLA (Future Business Leaders of America) club recently participated in the FBLA State Leadership Conference and Competition. Club advisor, Laurie Roberge, accompanied students to the competition held at the Crown Plaza Hotel in Cromwell on March 31st. Depending upon the event, the competition included on-line testing, performance, and virtual competitions.

Bristol Central High School is pleased to announce these students who were recognized as having scored in the top 5 in the state:

2014 FBLA State Leadership Conference

1st Place – Virtual Business Management (team event),
Winners are Will Jabs, Bob Jacques, and Brittani Murphy

1st Place – Business Calculations winner is Bob Jacques

1st Place – Introduction to Parliamentary Procedure winner is Cameron Reed

The students were present in the audience and stood to be acknowledged by the Board.

Bristol Central - National Latin Exam Results

Sixty students at Bristol Central High School recently received very high scores on the thirty-seventh annual National Latin Exam. In March, students in Kelly Monahan-DiNoia's Latin I, II, III and IV classes took the exam which is sponsored by the American Classical League and the National Junior Classical League. BCHS Latin students competed against 154,000 Latin students from forty-nine states (only Iowa abstained) and foreign countries including: Australia, Canada, China, France, Germany, Indonesia, Italy, Japan, Netherlands, New Zealand, Oman, Phillipines, Poland, Singapore, South Korea, Spain, Turkey, the United Kingdom, and Zimbabwe.

In its inaugural year, 1978, approximately 9,000 students participated in the exam, and the number has grown steadily each of its thirty-seven years to reach its current level. The birth, growth, and success of the NLE are all the results of a cooperative venture which has linked elementary-, middle-, high-school, and college teachers across the nation and the world.

The very competitive National Latin Exam tests students' knowledge of ancient Roman language, grammar, literature, geography, daily life, mythology, history, and English derivatives. There are also comprehension questions based on a short passage. The test has a time limit of 45 minutes. The BCHS winners will be recognized at the school's awards ceremony in June.

Perfect Papers

Arianna Olson, the daughter of Dr. Neil Olson and Katherine Bartucca-Olson achieved a perfect score on the Latin I exam.

Andrew Rajotte, the son of Mark and Andrea Rajotte, also attained a perfect score on the Latin I exam.

Arianna and Andrew were in the audience and stood to be recognized by the Board.

Teacher Selection for the CT Dream Team

We are pleased to announce that nine Bristol teachers were selected to be members of the Connecticut Dream Team. 97 teachers from 86 schools across Connecticut were selected by the State Department of Education for this team. The teachers selected were chosen through a competitive statewide application on the basis of their content knowledge and understanding of the Common Core State Standards. Each educator demonstrated their commitment and ability to "scale their impact" beyond the classroom.

The members of the Connecticut Dream Team participated in *TeachFest Connecticut*, an intensive, structured working session on April 25-27. These teachers will continue to participate in online learning sessions. The Team members will translate their teaching methods and classroom expertise into high-quality Common Core resources for use by teachers in Connecticut. The Dream Team will serve as teacher leaders for a "Common Core Fest" to be held for hundreds of teachers across the state on July 29, 2014.

Congratulations to our Bristol teachers who are members of the Connecticut Dream Team: Kelly Bouchard, Sharon Campolo, Amy Di Noia, Marilz Fitzpatrick, Barbara McLean, Corey Nagle, Elizabeth Porter, Debra Vitale, Joanna Vastola.

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Teacher Selection for the CT Dream Team – con't

Members of the Dream Team stood to be recognized by the Board.

2014 Staff Achievement Award Recipients

Each year the Board of Education selects staff members who go above and beyond the expectations of their job description to be honored with a Staff Award. A dinner in their honor will be held on May 28, 2014 at 5:30 p.m. Award winners were present in the audience and stood to be recognized.

AWARD RECIPIENTS:

Distinguished Administrator:

Carly Fortin - Principal - Bristol Eastern High School

1st Time Awardees:

Stephane Blais - Head Custodian - West Bristol School

Holly Caruso-Pugliese - Kindergarten Teacher - Mountain View School

Carolyn Kielma - Biology, AVID Elective Teacher - Bristol Eastern High School

Margaret Negron - 8th Grade Special Education Teacher - Chippens Hill Middle School

Career Achievement Award:

G. Gale Dickau - English Teacher - Bristol Central High School

Chairman Amara called for a short recess to allow for award recipients' and their families to leave if they wished.

APPROVAL OF MINUTES

Approval of the April 2, 2014 Regular Meeting as written.

On motion of Commissioner Dolan seconded by Commissioner Fitzgerald it was unanimously

VOTED: The Board of Education approve the April 2014 Regular Meeting Minutes as written.

COMMITTEE REPORTS

Operations – Commissioner Hintz reported that committee continues to look at policies specifically: Gifts, Bequests and Donations.

Finance – Commissioner Fitzgerald reported that the committee met on Thursday, April 10, 2014 and the Year To Date Financial Report and Reforecast was presented by the Director of Finance, Gary Franz. The General Fund operating budget for the fiscal year July 1, 2013 thru June 30, 2014 is \$ 104.2 million, with a 1% prior year reserve of \$ 1,026,859; the total operating budget for the fiscal year is \$ 105.3 million. Expenditures thru March 31st total \$ 71.2 million with encumbrances of \$ 7.1 million; the current reforecast for the fiscal year is \$ 105.3 million, with projected operating favorability of \$ 5,901. Total unplanned expenditures year to date are \$ 493,534; the identified savings total \$ 895,261. There is further risk and exposure of \$ 1.6 million through the end of the fiscal year as a result of longevity payments for non-certified staff totaling \$ 174,043, Regular transportation totaling \$ 461,729, Operation of Plant \$ 168,689 due to projected electricity utilization and natural gas; and Special Education totaling \$ 675,844 for out of district students and transportation. The Food Services operating deficit is projected at \$ 201,277 for 2013-2014. The next Finance committee meeting is scheduled of May 22nd to report on year to date results thru April 2014.

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Personnel – Commissioner Dolan reported that the committee met to discuss the nominations for the Staff Awards and convened into Executive Session to discuss Non-Bargaining contract and Local 3597 negotiations.

SUPERINTENDENT REPORT

Dr. Solek reported that the Joint Boards of the City of Bristol will meet to vote on the 2014-2015 Board of Education budget on May 19, 2014 at 6:30 p.m. in City Council Chambers. Many parents have asked about the status of Full Day Kindergarten related to this vote, and we will have a final word on FDK pending the vote. The Bristol Early Childhood Alliance is hosting a community conversation on Wednesday, May 21st from 4:45 to 8:30 p.m. at the Bristol Senior Center. These are valuable community tools to examine issues affecting children, youth and families. She is proud to announce the Connecticut 30 Alliance District of which Bristol is a member convened on May 1st at the Institute of Technology and Business Development in New Britain. Bristol's Office of Teaching and Learning and select faculty were asked to present to the group regarding Bristol's Teacher Literacy Coaching Model; which is unique to the Bristol Schools. Presenters were Denise Carabetta, Dr. Susan Moreau, Dr. Pam Brisson, District Math Supervisor, Lisa Bernabe and three Literacy Coaches: Amy DiNoia, Derek LaChance and Lisa Rocco. Finally, teacher David Hayes has served on the CREC Uniform Regional Calendar Committee. The regional calendar draft is similar to the calendar which is currently used in the Bristol Schools. The State Legislators are looking at adopting a uniform school calendar for all public schools in the State of Connecticut. As of this Monday, the proposal, and the committee's recommendations went before the State Legislators for consideration. Stay tuned for updates.

CONSENT AGENDA

Personnel

New Administrator Hires

Molly Goodine - BOE - Special Services Supervisor - Effective July 1, 2014

Gwen Killheffer - BOE - Special Services Supervisor - Effective May 5, 2014

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the New Administrator Hires.

Teacher Retirement

Nancy Graziano - GH - Special Education – Effective June 30, 2014

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education accept the Teacher Retirement.

Teacher Resignations

Sara Feshazion - BEHS - Science - Effective June 30, 2014

Ann Marie Spinelli - CW - Math Coach - Effective April 21, 2014

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education accept the Teacher Resignations.

A-3 Teacher Appointment

Dennis Griffin - BEHS - English Curriculum Coordinator - Effective April 22, 2014

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

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VOTED: The Board of Education approve the A-3 Teacher Appointment.

Coaching Resignation

Thomas Chauvin - Head Girls Tennis Coach - BEHS - Effective 6/19/14

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education accept the Coaching Resignation.

Coaching Appointment

Jeffrey Papazian - Head Football Coach - BCHS - Effective 5/8/14

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the Coaching Appointment.

Grants

K-3 Literacy Expansion Grant

This grant will support the use of materials to develop data on student development of early reading skills and guide the use of appropriate remedial activities to improve student achievement. The program will be implemented at West Bristol School.

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the K-3 Literacy Expansion Grant.

Approval of the Year 3 Alliance Grant Application

Bristol was designated an Alliance District at the start of the 2012-13 school year. This grant application outlines how the allocated funds will be expended. Currently, our K-12 literacy coaches, two administrative positions, some preschool staff and a variety of professional development opportunities are funded through these grant dollars.

Our 2014-15 grant request allocates funds to full day kindergarten teachers and an Instructional Technology staff whose responsibilities will include serving as the direct contact for all hardware and software issues for all on-line testing of students including Smarter Balanced Assessment and NWEA – Measures of Academic Progress.

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the Approval of the Year 3 Alliance Grant Application.

TOPS Grant - Translation, Outreach, Programming and Support Services

Bristol FRCs are requesting \$5,000 of funding from the Main Street Foundation General Fund to implement TOPS (Translation, Outreach, Programming and Support Services) for Spanish speaking parents/children residing in the West Bristol School district. Grant Funds will be used to hire a per diem Spanish Speaking Outreach Worker to provide culturally competent social work services to parents/children ensuring that their educational needs and family goals are achieved (approx. 8 hours per week). The FRC Outreach Worker will provide translation services at PPTs, parent-teacher conferences and other needed correspondence done in Spanish. In addition, we expect to complete at least 25 Family Assessments. The Outreach Worker will use the Family-Partnership Assessment tool which will assist parents in identifying their needs in the following areas: education, employment, housing, transportation, support service needs, health/wellness, finances, childcare/parenting. The parents will then be connected to FRC and community services to meet their identified needs.

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TOPS Grant - Translation, Outreach, Programming and Support Services – con't

On motion of Commissioner Dolan seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the TOPS Grant - Translation, Outreach, Programming and Support Services.

Public Comment

Calvin Brown – 286 Ivy Drive – Addressed the Board regarding Cafeteria Workers and Bullying.

Pauline Suszuzynski – 14 Seminary Street - Addressed the Board regarding Cafeteria Workers.

Gia Sirlce – 20 Melrose Street – Addressed the Board regarding the Cafeteria.

Liz Davis – 124 Garfield Street – Addressed the Board regarding the Cafeteria.

Carol Duval – 237 Wolcott Street – Addressed the Board regarding the Cafeteria

Sharon Peterson – 72 Kimberly Lane – Addressed the Board regarding the Cafeteria.

Steve Roberts – 71 Collier Avenue – Addressed the Board regarding the Cafeteria.

Valerie Jankoski – 26 Wilderness Way – Addressed the Board regarding the Cafeteria.

Roy Diyulio – 83 Collier Avenue – Addressed the Board regarding the Cafeteria.

Kathy Martin – 466 Hill Street – Addressed the Board regarding Outsourcing the cafeteria.

Jim Jankoski – 26 Wilderness Way – Addressed the Board regarding BOE Function.

Mike Petosa – 30 Walnut Street – Addressed the Board regarding the Cafeteria.

Chad Lockhart – 103 Duncan Street – Addressed the Board regarding the Cafeteria.

Dylan Cushing – 214 Brentwood Drive – Addressed the Board regarding Music.

Tom Doyle – 181 Sherwood Road – Addressed the board regarding the cafeteria.

John Stavens – 100 Garfield Street – Addressed the Board regarding the Cafeteria

Deliberated Items/District Leadership Team Reports

BCHS French Exchange and Belgium 2015

As part of our ongoing efforts to broaden the horizons of our students, as well as meet the national, state and curricular standards of world language learning, we hope to continue the exchange between BCHS and the students of the Lycée Jean Monnet that is currently in its fifth cycle (tenth year). The French teachers and students came to stay with us in March of 2014. They were housed by Bristol families and attended classes with their correspondents. In April of 2015, we hope to send our students to a similar experience in France. Students will be staying in the homes of the students who came to Bristol. They will attend classes and will be able to have excursions to Paris, Normandy, and Versailles. Our French exchange partners live about forty-five minutes outside of Paris. All costs of food and housing will be borne by the host families. Our French counterparts will plan the excursions and we will use First Student for the bus and Globe Travel to handle the airline tickets. This year's proposal includes an additional 3 days to tour Brussels, Belgium. We would be touring Medieval Brussels, the Royal Palace as well as visiting the imposing European Union

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BCHS French Exchange and Belgium 2015 – con't

buildings located in the heart of Brussels. French-speaking Belgium is an integral part of the new curriculum that the Bristol Public Schools have adopted in the last 2 years and will continue to adopt over the next 2 years.

On motion of Commissioner Hintz seconded by Commissioner Vibert it was unanimously

VOTED: The Board of Education approve the BCHS French Exchange and Belgium 2015.

Elementary and Secondary Summer School Offerings - Summer 2014

Bristol offers a variety of Summer School programming for students in Kindergarten through Grade 12.

Elementary:

Enrichment: These courses provide enrichment activities for elementary students. This program will be held at Ivy Drive School.

Middle School:

District Program: This program offers the opportunity for students to make up courses for which they did not receive a passing grade. Grade 6-7-8 students required to make-up courses attend on a non-tuition paying basis. This program will be held at Bristol Eastern High School.

High School:

District Program: Courses offered in this program allow students to obtain credit for courses not successfully completed during the academic year. Grade 9 and 10 students required to make-up courses attend on a non-tuition paying basis. Students pay tuition for grade 11 and 12 classes. This program will be held at Bristol Eastern High School.

Costs:

The Board of Education policy on summer school states that Bristol students in grades 6, 7, 8, 9, and 10, who are making up failed courses, will not be charged tuition. Bristol students making up failed courses from grades 11 and 12 and non-Bristol residents will be charged tuition. The BOE budget funds the teaching positions for make-up of failed courses in grades 6, 7, 8, 9 and 10 as per the BOE policy.

On motion of Commissioner Vibert seconded by Commissioner Fitzgerald it was unanimously

VOTED: The Board of Education approve the Elementary and Secondary Summer School Offerings - Summer 2014.

Enrollment Update

Board of Education Members have asked to receive a quarterly review of enrollment figures. Dennis Bieu, Human Resource Director presented the most recent enrollment figures.

Parent Conference Schedules and Marking Period Close Dates for 2014-2015

Parent-teacher conferences are scheduled for the fall and spring at the elementary, middle and high school levels.

The school year is divided into three marking periods for the elementary and middle school students and four marking periods for high school students. This creates marking periods of approximately 60 days and 45 days for grades K-8 and 9-12 respectively.

On motion of Commissioner Vibert seconded by Commissioner Hintz it was unanimously

VOTED: The Board of Education approve the Parent Conference Schedules and Marking Period Close Dates for 2014-2015.

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Education Specifications for the Northeast Middle School Roof Project

Replacement of the Northeast Middle School Roof requires the Education Specifications be approved by the Board of Education and then reviewed and approved by the Building Committee. This is a state requirement.

On motion of Commissioner Vibert seconded by Commissioner Hintz it was unanimously

VOTED: That the Board of Education approve the Education Specifications for the Northeast School Roof Project located at Northeast Middle School at 530 Stevens Street.

Textbook Adoption

AP Biology Textbook Adoption - First Reading

Two years ago, the College Board required the district to revise the AP Biology curriculum. In support of that revision, the College Board is now requiring the schools to upgrade the textbook for the class to meet the revised curriculum standards. After a review of several possibilities, the textbook selection committee recommends the following textbook for AP Chemistry:

Cambell Biology in Focus by Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson, and Jane B. Reece.

This is the First Reading of the text. Please direct any questions in the intervening month to Dr. Gagliardi.

AP Chemistry Textbook - First Reading

Last year, the College Board required the district to revise the AP Chemistry curriculum. In support of that revision, the College Board is now requiring us to upgrade the textbook for AP Chemistry. After a review of several textbook options, the textbook selection committee recommends the following textbook for AP Chemistry:

Chemistry: The Central Science by Theodore E. Brown, H. Eugene H LeMay, Bruce E. Bursten, Catherine Murphy, and Patrick Woodward

This is the First Reading of the text. Please direct any questions in the intervening month to Dr. Gagliardi.

Policy Revision

Policy 5113 - Excused Absences - First Reading

A change in the Connecticut Statutes in July 2013, changed the definition of excused and unexcused absences. A letter was sent to every family explaining these changes at the start of the 2013-14 school year. This policy revision brings our policy into compliance with state statutes.

This is the First Reading of the text. Please direct any questions in the intervening month to Dr. Moreau.

Old Business

Engagement of a Private Contractor to Provide Cafeteria Services

On motion of Commissioner O'Brien seconded by Commissioner Dolan it was

VOTED: To authorize the Superintendent to execute a contract with Whitson's in the form approved by the State Department of Education, to be effective July 1, 2014.

Chairman Amara read information regarding the cafeteria outsourcing timeline.

Commissioners were invited to discuss the motion on the table.

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Engagement of a Private Contractor to Provide Cafeteria Services – con’t

On motion of Commissioner Vibert seconded by Commissioner Hintz it was

VOTED: To table the initial motion for at least one calendar school year (2014-2015) and work with the union under the tentative agreement as well as our vendors to see if we can work this out without privatizing.

Chairman Amara explained that a Yes vote would indicate an extension of discussion with the union. Chairman Amara declared the motion **FAILED** after a roll call vote of six (6) commissioners (O’Brien, Fitzgerald, Dolan, Dube, Morgan and Amara) Opposed and two (2) Commissioners (Vibert, Hintz) In Favor. Commissioner Hintz.

The original motion was read again, ***To authorize the Superintendent to execute a contract with Whitson’s in the form approved by the State Department of Education, to be effective July 1, 2014.***

Chairman Amara declared the motion **PASSED** after a roll call vote of five (5) commissioners (Fitzgerald, Dolan, Dube, Morgan and Amara) In Favor and three (3) Commissioners (O’Brien, Vibert and Hintz) Opposed.

Commissioner Vibert reported on the students who live in Cambridge Park. A committee has been formed by Principal Kris Irvine regarding the “Walking School Bus”. They have started, and they will be walking one day a week on Wednesdays. Commissioner Vibert has obtained some private funds to purchase treats for the students, she passed around a photo of the students walking.

New Business

Commissioner Vibert wanted to know if the Administration could arrange an administrator/teacher walk thru of Memorial Boulevard based on the picture that was in the paper which showed several items that were left behind and could be useful to the district or other area schools. Dr. Moreau explained that when the building was turned over to the City, there were auctions held and that we were never notified of any items that needed to be retrieved by the district.

Information

Commissioner Dolan reported that he attended the SEPTO meeting last night, because there was a good program regarding Autism and was well attended. He would like to see more people in attendance.

Adjournment

The being no other business to come before the Board of Education and

On motion of Commissioner Dolan and seconded by Commissioner O’Brien, the meeting was adjourned. (9:20 p.m.)

Respectfully Submitted

Susan P. Everett

Susan P. Everett

Executive Secretary to Board of Education

CONNECTICUT INTERSCHOLASTIC ATHLETIC CONFERENCE

CONCUSSION MANAGEMENT AND RETURN TO PLAY REQUIREMENTS

“WHEN IN DOUBT – SIT IT OUT”

A concussion is a type of traumatic brain injury or (TBI), “that changes how the cells in the brain normally work. A concussion is caused by a blow to the head or body that causes the brain to move rapidly inside the skull. Even a “ding,” “getting your bell rung,” or what seems to be a mild bump or blow to the head can be serious. Concussions can also result from a fall or from players colliding with each other or with obstacles, such as a goalpost” (Centers for Disease Control and Prevention, 2009).

PART I -- SIGNS AND SYMPTOMS OF A CONCUSSION

– A concussion should be suspected if any one or more of the following signs or symptoms are present, or if the coach/evaluator is unsure.

1. Signs of a concussion may include (what the athlete looks like):

- Confusion / disorientation / irritability
- Trouble resting / getting comfortable
- Lack of concentration
- Slow response / drowsiness
- Incoherent / slurred speech
- Slow / clumsy movements
- Loss of consciousness
- Amnesia / memory problems
- Act silly / combative / aggressive
- Repeatedly ask same questions
- Dazed appearance
- Restless / irritable
- Constant attempts to return to play
- Constant motion
- Disproportionate / inappropriate reactions
- Balance problems

2. Symptoms of a concussion may include (what the athlete reports):

- Headache or dizziness
- Nausea or vomiting
- Blurred or double vision
- Over sensitivity to sound / light / touch
- Ringing in ears
- Feeling foggy or groggy

Note: Public Act No. 10-62 requires that a coach MUST immediately remove a student-athlete from participating in any intramural or interscholastic athletic activity who (A) is observed to exhibit signs, symptoms or behaviors consistent with a concussion following a suspected blow to the head or body, or (B) is diagnosed with a concussion, regardless of when such concussion or head injury may have occurred.

PART II – RETURN TO PARTICIPATION (RTP)

– Currently, it is impossible to accurately predict how long concussions will last. There must be full recovery before someone is allowed to return to participation. Connecticut Law now requires that no athlete may resume participation until they have received written medical clearance from a licensed health care professional (Physician, Physician Assistant, Advanced practice Registered Nurse, Athletic Trainer) trained in the evaluation and management of concussions.

Concussion management requirements:

1. No athlete SHALL return to participation (RTP) on the same day of concussion.
2. Any loss of consciousness, vomiting or seizures the athlete MUST be immediately transported to the hospital.
3. Close observation of an athlete MUST continue following a concussion. This should be monitored for an appropriate amount of time following the injury to ensure that there is no escalation of symptoms.
4. Any athlete with signs or symptoms related to a concussion MUST be evaluated from a licensed health care professional (Physician, Physicians Assistant, Advanced Practice Registered Nurse, Athletic Trainer) trained in the evaluation and management of concussions.

5. The athlete MUST obtain written clearance from one of the licensed health care professionals mentioned above directing them into a well defined RTP stepped protocol similar to one outlined below. If at any time signs or symptoms should return during the RTP progression the athlete should cease activity*.
6. After the RTP protocol has been successfully administered (no longer exhibits any signs or symptoms or behaviors consistent with concussions), final written medical clearance is required by one of the licensed health care professionals mentioned above for them to fully return to unrestricted participation in practices and competitions.

Medical Clearance RTP Protocol (Recommended one full day between steps)

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
1. No activity	Complete physical and cognitive rest until asymptomatic. School may need to be modified.	Recovery
2. Light aerobic activity	Walking, swimming or stationary cycling keeping intensity, <70% of maximal exertion; no resistance training	Increase Heart Rate
3. Sport Specific Exercise	Skating drills in ice hockey, running drills in soccer; no head impact activities	Add Movement
4. Non-contact training drills	Progression to more complex training drills, i.e., passing drills in football and ice hockey; may start progressive resistance training	Exercise, coordination and cognitive load
5. Full Contact Practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff

* If at any time symptoms should return during the RTP progression the athlete should stop activity that day. If the athlete's symptoms are gone the next day, s/he may resume the RTP progression at the last step completed in which no symptoms were present. If symptoms return and don't resolve, the athlete should be referred back to their medical provider.

References:

1. NFHS. Concussions. 2008 NFHS Sports Medicine Handbook (Third Edition). 2008: 77-82.
<http://www.nfhs.org>
2. McCrory, Paul MBBS, PhD; Meeuwisse, Willem MD, PhD; Johnston, Karen MD, PhD; Dvorak, Jiri MD; Aubry, Mark MD; Molloy, Mick MB; Cantu, Robert MA, MD. Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport Held in Zurich, November 2008. Clinical Journal of Sport Medicine: May 2009 - Volume 19 - issue 3 - pp 185-200
http://journals.www.com/cjsportsmed/Fulltext/2009/05000/Consensus_Statement_on_Concussion_in_Sport_3rd.1.aspx
3. Centers for Disease Control and Prevention. *Heads Up: Concussion in High School Sports*.
http://www.cdc.gov/NCIPC/tbi/Coaches_Tool_Kit.htm.
4. U.S. Department of Health and Human Services Centers for Disease Control and Prevention. *A Fact Sheet for Coaches*. (2009). Retrieved on June 16, 2010. [Http://www.cdc.gov/concussion/pdf/coaches_Engl.pdf](http://www.cdc.gov/concussion/pdf/coaches_Engl.pdf)

Resources:

- Centers for Disease Control and Prevention. *Injury Prevention & Control: Traumatic Brain Injury*. Retrieved on June 16, 2010.
<http://www.cdc.gov/TraumaticBrainInjury/index.html>
- Centers for Disease Control and Prevention. *Heads Up: Concussion in High School Sports Guide for Coaches*. Retrieved on June 16, 2010.

ED114 FISCAL YEAR 2015

BUDGET FORM

FUNDING STATUS:

GRANTEE NAME: BRISTOL PUBLIC SCHOOLS

TOWN CODE: 00017

GRANT TITLE: IDEA, PART B, SECTION 611

PROJECT TITLE: IDEA, PART B, Section 611 ENTITLEMENT GRANT

CORE-CT CLASSIFICATION:

FUND: 12060 SPID: 20977

PROGRAM: 82032

BUDGET REFERENCE: 2015

CHARTFIELD1: 170002

CHARTFIELD2:

GRANT PERIOD: 7/01/14 - 6/30/16

AUTHORIZED AMOUNT:\$ 1,712,438

AUTHORIZED AMOUNT by SOURCE:

CURRENT DUE:\$

LOCAL BALANCE:\$

CARRY-OVER DUE:\$

CODES	DESCRIPTIONS	PUBLIC	NON PUBLIC	TOTAL
111A	NON-INSTRUCTIONAL SALARIES	\$ 91,821		\$ 91,821
111B	INSTRUCTIONAL SALARIES	\$1,479,127		\$1,479,127
200	PERSONAL SERVICES-EMPLOYEE BENEFITS	\$ 26,056		\$ 26,056
321	TUTORS (INSTRUCTIONAL, NON-PAYROLL)			
322	IN SERVICE	\$ 22,850		\$ 22,850
323	PUPIL SERVICES (NON-PAYROLL)		\$ 37,622	\$ 37,622
324	FIELD TRIPS			
325	PARENT ACTIVITIES			
330	EMPLOYEE TRAINING (NON-DIRECT SERVICES)			
341	AUDIT			
350	TECHNICAL SERVICES			
440	RENTALS			
450	CONSTRUCTION SERVICES			
510	STUDENT TRANSPORTATION SERVICES			
530	COMMUNICATIONS			
560	TUITION			
580	TRAVEL			
650A	SUPPLIES-TECHNOLOGY RELATED			
650B	INSTRUCTIONAL SUPPLIES	\$ 54,962		\$ 54,962
730	EQUIPMENT			
734	TECHNOLOGY RELATED HARDWARE			
735	TECHNOLOGY SOFTWARE			
917	INDIRECT COSTS			
	TOTAL	\$1,674,819	\$ 37,622	\$1,712,438

ED114 FISCAL YEAR 2015

BUDGET FORM

FUNDING STATUS:

GRANTEE NAME: BRISTOL PUBLIC SCHOOLS

TOWN CODE: 00017

GRANT TITLE: IDEA, PART B, SECTION 619

PROJECT TITLE: IDEA, PART B, Section 619 Preschool Entitlement

CORE-CT CLASSIFICATION:

FUND: 12060

SPID: 20983

PROGRAM: 82032

BUDGET REFERENCE: 2015

CHARTFIELD1: 170002

CHARTFIELD2:

GRANT PERIOD: 7/01/14 - 6/30/16

AUTHORIZED AMOUNT:\$ 58,324

AUTHORIZED AMOUNT by SOURCE:

CURRENT DUE:\$

LOCAL BALANCE:\$

CARRY-OVER DUE:\$

CODES	DESCRIPTIONS	PUBLIC	NON PUBLIC	TOTAL
111A	NON-INSTRUCTIONAL SALARIES			
111B	INSTRUCTIONAL SALARIES	\$ 48,324		\$ 48,324
200	PERSONAL SERVICES-EMPLOYEE BENEFITS			
321	TUTORS (INSTRUCTIONAL, NON-PAYROLL)			
322	IN SERVICE			
323	PUPIL SERVICES (NON-PAYROLL)			
324	FIELD TRIPS			
325	PARENT ACTIVITIES			
330	EMPLOYEE TRAINING (NON-DIRECT SERVICES)			
341	AUDIT			
350	TECHNICAL SERVICES			
440	RENTALS			
450	CONSTRUCTION SERVICES			
510	STUDENT TRANSPORTATION SERVICES			
530	COMMUNICATIONS			
560	TUITION			
580	TRAVEL			
650A	SUPPLIES-TECHNOLOGY RELATED			
650B	INSTRUCTIONAL SUPPLIES	\$ 10,000		\$10,000
730	EQUIPMENT			
734	TECHNOLOGY RELATED HARDWARE			
735	TECHNOLOGY SOFTWARE			
917	INDIRECT COSTS			
	TOTAL	\$ 58,324		\$ 58,324

Educational Travel Experience Designed Especially for Bristol Eastern High School



The Best of Italy - 61531-10

June 26 - July 5, 2015

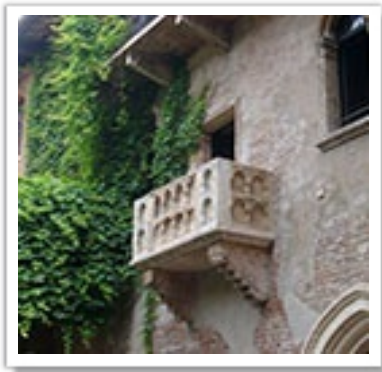
ITINERARY OVERVIEW

- DAY 1 DEPARTURE FROM NEW YORK
- DAY 2 ARRIVE MILAN - VERONA - VENICE/LIDO (2 NIGHTS)
- DAY 3 VENICE (LA SERENISSIMA)
- DAY 4 VENICE AREA - RAVENNA - PISA - TUSCANY (2 NIGHTS)
- DAY 5 FLORENCE (CRADLE OF THE RENAISSANCE)
- DAY 6 TUSCANY - SIENA - NAPLES AREA (1 NIGHT)
- DAY 7 POMPEII & MT VESUVIUS - NAPLES - ROME (3 NIGHTS)
- DAY 8 ROME (THE CITY OF THE CAESARS)
- DAY 9 ROME (THE CITY OF THE POPES)
- DAY 10 DEPARTURE FROM ROME

ITINERARY

Italy calls to people in a unique way. The rich and colorful culture melts into a warm atmosphere filled with light and life. Ancient traditions combine with a spiritual pride expressed in the art and food that epitomize what we have come to know as La Bella Vita. There is something about this country that stirs the soul as much as it educates the mind. From Roman ruins to the richness of the Renaissance, from the ruins of war to the peace of country life, experience the world in a new way in beautiful Italy.

 Educational Tour/Visit	 Cultural Experience	 Concert Performance	Transportation
 Recreational Activity	 LEAP Enrichment	 Sporting Fixture	



DAY 1 Friday, 26 June 2015

-  Relax and enjoy our scheduled flight from New York City.

DAY 2 Saturday, 27 June 2015

Our 24-hour Tour Director will meet us at the airport and remain with us until our final airport departure.

-  We will have use of a private coach and driver while touring today.
-  Verona is a vibrant city that has grown to be one of the most prosperous in northern Italy. Despite its magnificent Roman center and unique palazzi, the town is still primarily known as the setting of Shakespeare's Romeo and Juliet.
-  Tour Verona's Roman Amphitheater, the largest in the world. Completed in 30 AD, this arena has been the site of executions, fairs, bullfights, opera and theater productions, and, of course, gladiatorial combat.
-  Take a guided Walking Tour, highlighting the city's most important landmarks and monuments, including the Casa di Giulietta, where we will see the balcony rumored to be that of Juliet, from Shakespeare's Romeo and Juliet. Also along our walk we will view the picturesque Erbe and Lord's Squares, the Tombs of the Scaligers, Castelvechio, and Scaligers Bridge.
- Our base for the next two nights will be Venice/Lido, where breakfast will be provided at the hotel.
-  Venice is one of the few cities in the world that can truly be described as unique. It was known as the gateway to the Orient, and during the Middle Ages became one of the most powerful city-states in the Mediterranean. Built on a series of islands connected by bridges and canals, Venice has survived all odds to become the intriguing and iconic city it is today.
-  The vaporetto is Venice's version of public transport, as no cars are allowed in this city on the water. While in Venice, we will each have a vaporetto pass for transportation and sightseeing.
-  This evening, dinner will be provided in a local restaurant.
-  Stroll through the city's narrow passageway to the Ponte Rialto (Rialto Bridge) the most elegant and famous of the bridges that span the Grand Canal.



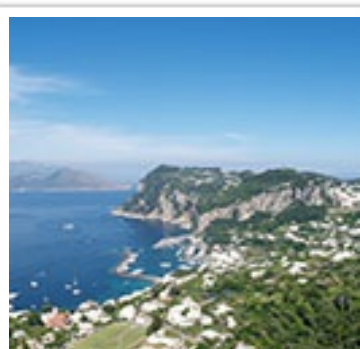
DAY 3 Sunday, 28 June 2015

During the course of our tour we will gain from the knowledge and insight of half-day local guides while we are here in Italy.

-  Take a vaporetto ride along the Grand Canal past Venice's beautiful palaces and cathedrals. We will also see the Rialto Bridge, the oldest and most famous of the bridges that span the Grand Canal.
-  Stroll through the St. Mark's Square. Bordered by Venice's greatest historic buildings, St. Mark's Square is the main focal point of the city and the center of its water transportation system, as well as the most popular place for people watching and picture taking. Visit St. Mark's Basilica, featuring interior walls encrusted with spectacular gold mosaics. Our visit will also include an ascent to the Galleries to see the original bronze horses that once adorned the facade, as well as a stunning view of St. Mark's Square.
-  Tour the Doge's Palace, former residence of the rulers of Venice. We will explore the ornate and grandiose rooms of the palace, including the Grand Council chamber, featuring Tintoretto's Paradise, said to be the world's largest oil painting. We will walk across the famous Bridge of Sighs to the cells where Casanova was once imprisoned.
-  Experience a Glass Blowing Demonstration at Vecchia Murano, which has been a world-famous center for glass making for centuries. Murano glass is characterized by its unique colors and is collected throughout the world. We will have the opportunity to watch the artisans at work, and possibly to buy their creations.
-  This evening, dinner will be provided in a local restaurant.

DAY 4 Monday, 29 June 2015

-  We will have use of a private coach and driver, while touring for the next four days.
-  Today we will travel from Venice to Florence. En route, we will stop in Ravenna & Pisa.
-  With ancient streets and peaceful piazzas, there is so much more to the town of Ravenna than the superb Byzantine mosaics for which it is famous. The city rose to power in the 1st century BC and was eventually made capital of the Western Empire. Although this power has waned, the city is still of vital importance to the arts and archaeology.
-  Discover the Mausoleum of Galla Placidia, a 5th century chapel that contains exceptional mosaics dating from antiquity. Translucent panels bring the mosaics alive in all their grace and harmony, vivid with peacock blue, moss green, Roman gold, eggplant, and burnt orange. Visit the octagonal-domed Museum and Basilica of San Vitale, which dates from the mid-6th century. The mosaics inside, among the most celebrated in the western world, are done in brilliant greens and golds.
-  During the Middle Ages, Pisa's powerful navy and strong trading position brought enormous wealth to the city. Following several conquests and the silting of the harbor, however, it fell into decline. Now Pisa is primarily visited for its interesting architecture.
-  View the breathtaking Piazza del Duomo. Known in Italy as the "Field of Miracles," the piazza contains the beautiful cathedral and baptistry, and the famous Leaning Tower of Pisa. Despite its sinking foundations, the tower stands as magnificently today as it did upon completion in 1350.
-  Stop just outside Florence and explore the Piazzale Michelangelo. Offering a splendid panoramic view of the city's domes and towers, this is a great location to take photos and view some of the local artists at work.
-  Florence is so deeply connected to the Renaissance movement in art and literature that it is often called the "Cradle of the Renaissance." A walk through the peaceful piazzas reveals the architecture and sculpture that have made this beautiful city one of the world's greatest artistic capitals.
-  For the next two nights, our base will be in Tuscany (area). Breakfast and dinner will be included at the hotel.



DAY 5 Tuesday, 30 June 2015

During the course of our tour we will gain from the knowledge and insight of one full-day local guide while we are here in Florence.

-  Visit the Accademia Gallery, where we will view Michelangelo's statuary masterpiece, David, and Botticelli's Madonna and Child.
-  **LEAP: The Great Renaissance Debate**
The Renaissance is packed with great minds who have shaped our world today. Discover and argue with your fellow group members, the merits of key players in the Renaissance to eventually determining who is the greatest Renaissance man or woman.
-  Enjoy the Piazza del Duomo, where the cathedral, tower, and baptistery exhibit the traditions of Florentine art from the Middle Ages to the Renaissance. We will observe the massive and detailed facade of the Duomo before viewing the baptistery's bronze doors, designed by Ghiberti and which Michelangelo commented were worthy to be the "Gates of Paradise." After a brief visit inside the Duomo, we will have the opportunity to do one of the following: ascend the Bell Tower; climb the narrow steps to the top of the Red Dome; or visit the spectacular interior of the Baptistery. (One admission included).
-  Spend time in the Piazza della Signoria, the political stage of Renaissance Florence and an open-air museum of sculpture.
-  Experience the Uffizi Museum, one of Italy's finest art museums, containing one of the most famous collections of paintings and sculptures in the world. Exhibitions include works by most of the acclaimed Italian artists, as well as German, Dutch, and Flemish masters. Of particular note are European paintings from the 13th to 18th centuries, which include works by da Vinci, Michelangelo, Raphael, Botticelli, Rembrandt, and Rubens.

DAY 6 Wednesday, 01 July 2015

-  Today we will travel from Tuscany to Naples area. En route, we stop in Siena.
-  Once a capital to rival Florence, Siena is Italy's prettiest medieval town, and still possesses the grandeur of the age when it was at its peak.
-  Visit the Duomo, highlighted by distinctive striped marble columns. Our visit will include the beautiful Piccolomini Library, designed to house the cathedral's collection of illuminated manuscripts. The magnificent room features an unrivaled ceiling and large frescoes depicting important events in the life of Pope Pius II.
-  Stroll through the narrow and winding streets of Siena to the Piazza del Campo, a vast and lively square in the heart of the city.
-  The region of Campania is one of the most culturally diverse in Italy. Influenced by Roman, Greek, Byzantine, Norman, Spanish, and French cultures, Campania is known for its gastronomy, music, architecture, and divine beauty.
-  Our base for the next night will be in Campania, where breakfast and dinner will be provided at the hotel.



DAY 7 Thursday, 02 July 2015

-  Pompeii is a ruined and partially buried Roman town-city near modern Naples in the Italian region of Campania, in the territory of the comune of Pompei. Along with Herculaneum, its sister city, Pompeii was destroyed, and completely buried, during a long catastrophic eruption of the volcano Mount Vesuvius spanning two days in AD 79.
 -  Explore the magnificent Roman ruins at Pompeii, which give a fascinating glimpse into Roman life. In 79 AD, the fury of nearby Mt. Vesuvius was unleashed upon this prosperous city, killing its 2,000 inhabitants and burying it under pumice and ash. Today, the excavations reveal the ruins of the city's amphitheatres, forum, baths, streets and splendid houses, some with their frescoes still visible. Finally we explore the Villa of the Mysteries outside the city walls.
 -  Ascend Mt. Vesuvius, the active volcano that dominates Campania. When it erupted in 79 AD, it destroyed most of the nearby Roman settlements, including Pompeii, Herculaneum, and Stabiae.
 -  Visit the National Archaeological Museum, one of the finest antiquities museums in the world. With its Roman and Greek sculpture, this museum contains one of Europe's most valuable archaeological collections, highlighted by the select Farnese acquisitions, and the mosaics and sculpture excavated at Pompeii and Herculaneum.
 -  We continue on our journey from Naples area to Rome.
 -  Known to many as the "Eternal City", Rome is the capital of Italy, with an uninterrupted history spanning two and a half thousand years. As one of the founding cities of western civilisation, Rome is filled with incredible historical sites. It is a city with many faces, encompassing medieval, renaissance, and modern. To define Rome is an impossible task, but to enjoy Rome is a wondrous experience.
- For the next three evenings we will enjoy the convenience of our centrally-located Rome hotel, where daily breakfast will be included.
-  In Rome, the cost of public transport is included for all group sightseeing. Escorted by our guide, we will be able to experience the city in the same manner as the local people.
 -  This evening, dinner will be provided in a local restaurant.

DAY 8 Friday, 03 July 2015

-  Enjoy a guided tour, through the spectacular remains of the Roman Empire. The Colosseum, considered to be the greatest symbol of Ancient Rome's power and glory, was completed under Titus in 80 A.D. The Colosseum could hold 55,000 spectators, on a par with many of today's modern sports stadiums. Among the sights included is the Arch of Constantine, a triumphal arch finished in 315 A.D., commemorating the victory of Constantine I over Maxentius in the year 312 A.D. We will also tour the ruins and excavations of the Roman Forum, which features the remains of magnificent temples, basilicas, and triumphal arches that once formed the heart of the Empire.
-  Visit the Capitoline Museums, which house one of the greatest collections of classical sculpture in the world. Our visit includes the Picture Gallery, containing works from the 16th and 17th centuries by Caravaggio, Rubens, and Titian, among others.
-  Enjoy a view of Trajan's Column and Market. Completed in 113 A.D. as a monument to the Emperor Trajan, the column is most famous for its spiral bas-relief. It stands in front of the market, the ancient equivalent of a shopping center, which housed no less than 150 shops and offices. From there, stroll past the Victor Emmanuel Monument, a giant building created to honor the first king of a unified Italy.
-  Visit the Pantheon, Rome's best-preserved monument. The Pantheon is a masterpiece of architecture with its huge hemispherical dome. It also contains the tombs of the kings of Italy and that of the artist, Raphael.



DAY 8 Friday, 03 July 2015



This evening we will dine in the Piazza Navona area. Built on the foundations of Domitian's Circus, this magnificent square was designed by Borromini in 17th century. It is full of life and is highlighted by one of Rome's most spectacular fountains, the Four Rivers designed by Bernini. The square is often filled with local artists. The surrounding neighborhood is also one of the best places in Rome to get a tasty tartufo or gelato ice cream.

DAY 9 Saturday, 04 July 2015



Experience a specialist-guided tour of the Vatican City, including the Museums, home to one of the world's most impressive collections of art. Our tour includes the map tapestry rooms, the magnificent Raphael Rooms, and the spectacular Sistine Chapel, highlighted by Michelangelo's ceiling and his Last Judgment. We will continue into St. Peter's Square to visit St. Peter's Basilica, the largest church in the western world and the centre of Catholicism. Highlights of our visit include Michelangelo's Pieta and Bernini's magnificent Baldacchino over the high altar.



This evening we will dine near the spectacular Trevi Fountain where it is traditional to toss a coin into the fountain to ensure a safe return to The Eternal City. Spend time at Rome's meeting place, the Piazza di Spagna, home of the famous Spanish Steps. The piazza and steps are both named in reference to a 16th century Spanish ambassador who lived here. English poet John Keats lived and died in the house to the right of the steps, which is now a memorial.

DAY 10 Sunday, 05 July 2015



Our rewarding and enjoyable tour comes to an end as our Tour Director accompanies us to the airport on our final day.



TOTAL PER PERSON TOUR COST BASED ON NUMBER OF FULL-PAYING PARTICIPANTS

Bristol Eastern High School (Subject to final airfare confirmation)	Full Paying Participants	Free Place Entitlement	Price In USD	*With Early Discount
This proposal is valid until Saturday, 03 May 2014 and this tour cannot be operated in its present format with fewer than 10 participants. * Early Enrollment Discount of \$200 if enrolled by 05/03/2014.	22	3	4,599	4,399
EZ Pay Option				
Enroll by <i>05/03/2014</i> and make <i>12</i> payments of <i>\$341.58</i> every <i>30</i> days by automatic deduction from your bank account. The final payment of the series will be deducted no later than 45 days before travel. **Based on the bolded pricing ratio from above.				
Tour Prices Guaranteed at Time of Enrollment!				
Our Price Guarantee: Once you have accepted this proposal, the dates have been confirmed and the WorldStrides International Discovery Promotional Packs has been made available for your group's tour, the prices shown for the various group size levels will not change, regardless of any subsequent movements in airline fuel and taxes or currency fluctuations.				

What is Included:

- Round trip airfare with a major carrier on scheduled flights and guaranteed dates
- All airport taxes and fuel surcharges (which will not change after time of enrollment for any participant)
- Accommodation in three and four star hotels in triple or quad rooms with private facilities guaranteed throughout
- A filling breakfast everyday to get the day started well throughout your touring program
- A hearty three course dinner daily reflecting local cuisine on every evening (usually in local restaurants in capital cities)
- A full-time WorldStrides International Discovery programs Tour Director, familiar with our LEAP Enrichment Program, to accompany your group 24 hours a day from arrival to departure
- The expertise and perspective of local guides during your tour
- All excursions, cultural activities and (several pre-booked) admissions as per your itinerary
- Transportation by private coach for airport transfers and touring, except in the capital city, where public transport is used (and the cost included) for group sightseeing
- A free place in a single room and provision of an international cell phone for the main Program Leader on your tour
- Additional free places in shared twin rooms (as determined by the number of full paying participants stated below)
- Basic health insurance while on tour (including medical treatment on tour up to \$7,500) and \$50,000 of coverage for emergency evacuation and repatriation
- Free Professional Development Points/Credits (35 points or equivalent) for all faculty chaperones

This Does Not Include:

- Lunches or beverages with meals
- Visas (if required)
- Tips and gratuities for the guide and driver (or cruise staff if applicable)
- Any fees that might be imposed by the airlines at the airport for checked baggage
- Twin Room supplement at a rate of \$50 per night (mandatory for anyone 24 or above)
- Cancellation Protection Plus, which provides for cancellation for reasons not normally covered by insurance, at a rate of \$25 a day. Please note the rate will be reduced to \$20 a day if all the participants on the program choose to take this valuable assurance.

3/6/2014

Name: Barbara McLean

School: Ellen P. Hubbell Elementary School

Grade Level: Special Education Extended RR grades k-5

Rationale for becoming a mentor/cooperating teacher

My motivation to become a mentor/cooperating teacher comes from an internal drive to share my experiences in the field of special education with beginning teachers. In my eleven years working with special needs students, I am grateful to have encountered many positive learning experiences from my mentors in the field. As a lifelong learner, it is important that I give back to a profession that has given so much to me, by having the opportunity to work with teachers and learn from those who are just starting out in Special Education.

What I have to offer a student/beginning teacher

My experience working with para professionals has taught me valuable communication and time management skills when working with adults. Weekly morning meetings with the support staff in my program enables staff to collaborate and trouble shoot any learning/behavioral concerns. During morning meeting, I am able to provide clarification on student needs and feedback on student learning. Constructive feedback in a direct, but supportive manner is a critical skill in becoming a better teacher. I am open to allowing a beginning teacher to take over the class and try new strategies. Allowing a new teacher to try out their ideas will help them build confidence in their own abilities as they study the craft of teaching. I am a role model for professionalism and team cooperation. In special education, we are continuously adjusting schedules and instructional strategies to best meet student needs. As a lifelong learner, I am able to offer my experience using effective teaching strategies for exceptional learners. Ultimately, my experience can help a beginning teacher navigate through the many facets of special education and teaching in general.

April 30, 2014

Dear Ms. Carabetta

I am currently the Social Studies Department Chairman at Bristol Eastern High school where I teach mostly juniors and seniors in Civics, AP Government, and ELL Social Studies. I have been a teacher for 18 years, 16 in Bristol, and currently hold a Professional educator certificate. I feel I have a tremendous amount of experiences to offer a new teacher as they start on their career, which is why I am looking to join the Cooperating Teacher/TEAM mentoring program.

My role as Department Chairman has given me the opportunity to serve on the school's leadership team, which identifies the building goals as well as develops and implements the professional development based upon those goals. This has given me experience in guiding adult learners in expanding their teaching craft.

In addition, for the last four years I have been responsible for running the New Teacher Academy at Bristol Eastern High School. This monthly cohort meets to discuss the challenges faced by new teachers as they adjust to the demands of the profession. The topics I have discussed with them in the past include classroom management, personal time management, instructional strategies, differentiated instruction, effective use of data, and unit/lesson design. The implementation of the new teacher evaluation system has provided me the opportunity this past year to fully explore the Common Core of Teaching with the participants of the New Teacher Academy.

Outside of Bristol, I have been teaching two courses for the University of Phoenix in Curriculum and Assessment in Social Studies; one for k-8 and the other for grades 7-12. This course has allowed me to work with adult learners to help them understand the elements of Social Studies, lesson and unit creation, the integration of the Common Core State standards, and effective technology integration.

Over the last few years, I have truly enjoyed my opportunities to work with new teachers, which is why I have decided to apply for the Cooperating Teacher/TEAM mentoring program. It has been rewarding to help them develop their craft as an educator, and has proven to be an exciting challenge for me professionally. It has required me to fully develop my own understanding of education in order to successfully articulate it to others as they develop their own understanding. I have found new teachers typically have a high level of enthusiasm for the profession but can easily become overwhelmed with the various challenges educators face today. I enjoy sharing my experiences in order to help them find their way through these challenges to ensure their success in the profession.

I know my many years of experience, as well as my work as Department Chairman, and teaching for the University of Phoenix will help me be an effective mentor for a new educator. I look forward to participating in the Cooperating Teacher/TEAM mentoring program.

Sincerely,



Jeffrey Fleischman

Melissa Prentiss

Edgewood School, Grade 3

April 10, 2014

Becoming a mentor/cooperating teacher has been a long-term goal of mine since I completed my student teaching in 2004. I am thrilled that my principal has recommended me to this prestigious position. Throughout my tenure for the past ten years as a classroom teacher, I have gained a multitude of knowledge. I am confident that I can effectively communicate this knowledge to intrigued learners. I feel that I will be able to relate to aspiring teachers well because, I, myself completed my student teaching and began teaching not too long ago.

My cooperating teacher, Mrs. Belsito, was clearly an exceptional teacher. Through her careful guidance and constructive feedback, I learned how significant the role of a teacher is. I learned professional responsibilities and teacher leadership qualities that I continue to implement on a daily basis in my own classroom. I know that a lot of my success stems from the skills and qualities that I learned while student teaching. Student teaching is a time to acquire a wealth of knowledge. I feel that it is only then, that a prospective teacher has a glimpse of what being a teacher is really like. Internships, volunteering, and knowledge from books only brings one so far. One must be immersed in a true experience, like student teaching, to gain a full understanding of what will be expected from the teacher day to day. With an exceptional mentor/cooperating teacher, the student or beginning teacher will thrive and be very successful during this transition and during their career. Standards and curriculum goals have become so rigorous that all students are justified to expect an exceptional teacher to guide them.

Knowledge that I have gained from Mrs. Belsito, coupled with my own pedagogical skills will provide mentees/student teachers with the skills and qualities that will lead them to success. I know that my mentees/student teachers will also teach me things that I never tried or knew about. I know that together we will learn from one another and this will greatly benefit my students as well as their students. After all, exceptional teachers are what every student deserves.

I have a lot to offer a student or beginning teacher. I have and will continue to use the *Connecticut Common Core of Teaching (CCCT)* to reflect on my effectiveness as a teacher. I will model/demonstrate each of the six domains that are currently a part of the *CCCT*. During formal and informal observations of mentees/student teachers I will look for aspects of these domains in their daily lessons as well as in their demeanor. I will then meet with my mentees/student teachers to listen to their reflections and to add any feedback or suggestions that I may have. I will provide an open environment in which my mentees/students may make mistakes without fear of judgment. We all make mistakes; that's how we learn and grow. Instead, I will steer them towards more useful strategies when mistakes are made. I will be constructive, but remain confident and unyielding about what is expected from an exceptional teacher. I will be sympathetic, but sincere and vastly praise when lessons succeed and learning expectations are met. I will be positive and show my enthusiasm towards my love of teaching.

I will make myself available both before and after school to meet with my mentees/student teachers. I feel that this time is crucial to the learning process of becoming an effective teacher, so I will make myself available to meet whenever necessary. I will teach my mentees/student teachers how to incorporate the district/state/national standards into lessons. At first the task may seem very daunting. We will practice writing/matching essential questions and

objectives that are the foundation of every lesson. I will also provide pointers for things that are learned your first year such as organization, parental involvement and community relations.

My role as a mentor and cooperating teacher will enable me to reflect on my current teaching practices. I will be open to new suggestions from mentees/student teachers. I am confident that my position as a cooperating teacher will increase my reflective practitioner skills while simultaneously ensuring the needs of my mentees/student teachers are met. Being a successful teacher doesn't happen overnight, it takes years and years of practice, but starting off with a goal, high expectations, and acknowledgement is the first step.

After every lesson I reflect on what went well and what I should change. I think about how I can make this lesson even better so that I am as effective as I can be. I refer to the *CCCT* to judge my effectiveness as a teacher. Some exemplary skills that I think I possess as a teacher that relate to the *CCCT* are as follows: Each lesson that I design contains specific skills and concepts that match district/state/and national standards. I integrate areas of technology and literacy into daily math, science, and social studies lessons to promote growth among all learners. By doing so, it strengthens student's literacy skills through reading, writing, listening, speaking, viewing and presenting. Also, when students enter my classroom, a colorful classroom that meets their learning needs greets them. I have an extensive class library that appeals to students with diverse backgrounds and their interests. I have a wide selection of books at all performance levels. Students have easy access to materials so that they learn to become independent in time. Appropriate standards of behavior are created with the students on the first day of school so students have ownership of how they perceive the classroom environment should be. All of this knowledge that I have acquired through experience will be shared with my mentees/student teachers.

I have the ability to work cooperatively as a team member. I have established very positive relationships with all of my colleagues and I am always willing to share ideas or listen to suggestions. I have also taken part in several presentations to staff and the PTA, so I have had a significant amount of practice in relating information to adult learners.

I participate in several non-mandated professional activities. I try to take part in as many Dine and Discusses as possible to further my knowledge and thus become a more effective teacher. This year I have participated in 2 Dine and Discusses, K-5 Literacy Night, and a District Curriculum Group for grade 3.

I take the professional commitment of being a mentor/cooperating teacher very seriously. I know that student teachers and beginning teachers feel very overwhelmed and they need someone who is constructive, sympathetic, and exemplary to guide them along the right path. I am eager and excited to work with mentees/student teachers. I know that this experience will greatly benefit me as a teacher.

Students

Attendance/Excuses/Dismissal

Attendance

Connecticut state law requires parents to cause their children, ages five through eighteen inclusive, to attend school regularly during the hours and terms the public school is in session. Parents or persons having control of a child five years of age have the option of not sending the child to school until ages six or seven. Mandatory attendance terminates upon graduation or withdrawal with written parent/guardian consent at age seventeen.

A student is considered to be “in attendance” if present at his/her assigned school, or an activity sponsored by the school (e.g., field trip), for at least half of the regular school day. A student who is serving an out-of-school suspension or expulsion should always be considered absent. A student not meeting the definition of “in attendance” shall be considered absent.

Classroom learning experiences are the basis for public school education. Time lost from class is lost instructional opportunity. The Board of Education requires that accurate records be kept of the attendance of each child, and students should not be absent from school without parental knowledge and consent.

Excuses

A student’s absence from school shall be considered “excused” if written documentation of the reason for such absence has been submitted within ten (10) school days of the student’s return to school and meets the following criteria:

- A. For absences one through nine, a student’s absences from school are considered “excused” when the student’s parent/guardian approves such absence and submits appropriate documentation to school officials.

Such documentation includes a signed note from the student’s parent/guardian, a signed note from a school official that spoke in person with the parent/guardian regarding the absence, or a note confirming the absence by the school nurse or by a licensed medical professional, as appropriate. Documentation should explain the nature of and the reason for the absence as well as the length of the absence. Separate documentation must be submitted for each incidence of absenteeism. [See Form 5113]

Students

Attendance/Excuses/Dismissal

Excuses (continued)

B. For the tenth absence and all absences thereafter, a student's absences from school are considered excused for the following reasons:

1. Student illness (must be verified by a licensed medical professional to be deemed excused, regardless of the length of the absence);
2. Student's observance of a religious holiday;
3. Death in the student's family or other emergency beyond the control of the student's family;
4. Mandated court appearances (documentation required);
5. The lack of transportation that is normally provided by a district other than the one the student attends (no parental documentation required);
6. Extraordinary educational opportunities pre-approved by District administration and to be in accordance with Connecticut State Department of Education guidance.

C. A student's absence from school shall be considered unexcused unless:

1. The absence meets the definition of an excused absence and meets the documentation requirements; or
2. The absence meets the definition of a disciplinary absence, which is the result of school or District disciplinary action and are excluded from these State Board of Education approved definitions.

When the school in which a child is enrolled receives no notification from a parent or other person having control of the child is aware of the child's absence, a reasonable effort shall be made by school personnel or volunteers under the direction of school personnel to notify by telephone and by mail such parent or other person having control of the child.

The required mailed notice shall include a warning that two unexcused absences from school in one month or five unexcused absences in a school year may result in a complaint filed with the Superior Court alleging the belief that the acts or omissions of the child are such that the child's family is a family with service needs.

Responsibility for completion of missed classwork lies with the student, not the teacher. Unless a student has an extended illness, all make-up work will be complete within five days after the student returns to school.

Students

Attendance/Excuses/Dismissal

Dismissal (continued)

No student may be permitted to leave school at any time other than at regular dismissal without the approval of the student's parent/guardian. If a court official with legal permission to take custody of a child, or if a police officer arrests a student, the parent/guardian should be notified of these situations by the administration.

(cf. 5142 - Student Safety)

(cf. 5113.2 - Truancy)

(cf. 6113 - Released Time)

Legal Reference: Connecticut General Statutes

10-184 Duties of parents (as amended by PA 98-243 and PA 00-157)

10-185 Penalty

10-198a Policies and procedures concerning truants (as amended by P.A.11-136, An Act Concerning Minor Revisions to the Education Statutes.)

10-199 through 10-202 Attendance, truancy - in general

Action taken by State Board of Education on January 2, 2008, to define "attendance."

Action taken by State Board of Education on June 27, 2012, to define "excused" and "unexcused" absences.

Policy adopted:

BRISTOL PUBLIC SCHOOLS
Bristol, Connecticut
EXCUSED ABSENCE FORM

Student: _____

Grade: _____

School: _____

Date(s) of absence: _____

CT Statute 10-210 Reasons for excused absence:

- ☐ Illness (documentation may be required)
- ☐ Death in Family/Funeral
- ☐ Court Appearance (documentation required)
- ☐ Doctor appointment (documentation required)
- ☐ Dentist appointment (documentation required)
- ☐ Religious Observance
- ☐ Transportation no-show
- ☐ Extraordinary educational opportunity
- ☐ Other _____

Parent/Guardian Signature: _____

For Office Use

Absence Number _____

Excused _____

Unexcused _____

Instruction

Co-Curricular Activities are extensions of curricular courses which occur during the school day. Students participate in the course during the school day and participation in the co-curricular activity is required as part of the course. Examples of co-curricular activities are orchestra, band, or choral performances outside of the school day when the courses take place during the school day.

Extra-Curricular Activities are not-for-credit activities, for which there is no curriculum, and these activities take place outside of the school day. Examples include athletic teams, intramurals, clubs, and performances in plays.

Middle School and High School Extra-Curricular Activities /Athletics

District participation in interscholastic athletics shall be subject to approval by the Board. This shall include approval of membership in any leagues, associations, or conferences, of rules for student participation.

It is the Board's policy to provide students interscholastic athletic competition in a variety of sports. Qualified personnel shall be provided for coaching and supervising individual sports. In addition, it is the policy of the Board to provide intramural athletic activities as an outgrowth of class instruction in physical education commensurate with the grade level of the students involved.

Each student who chooses to participate in an interscholastic athletic program is required to have on file, in the offices of the building nurse, a certificate of consent, which is signed by the parent or legal guardian. No student may start practice for any athletic team until he or she has been examined and approved by a medical doctor. This certificate of consent shall be in effect for each student as specified in Sec. 5141.31.

The purpose of school athletics is both educational and recreational. The athletic program should encourage participation by as many students as possible and should be carried on with the best interests of the participants as the prime consideration. Participation should be without unreasonable interference with other obligations in the school, community and home.

It is recognized that a well-organized and well-conducted athletic program is a potent factor in the morale of a student body and an important phase of good community-school relations.

Every possible effort shall be made to offer equal opportunities for both sexes in sports and activities that shall include life sports that a student can carry through adulthood.

Instruction

Middle School and High School Extra-Curricular Activities /Athletics

In addition, the student participating on an interscholastic team agrees:

1. Not to participate on another team outside of school in the same sport while on the school's team (applicable to high school student-athletes only)
2. Not to receive any personal economic gain based upon athletic skill.
3. To participate under his or her own name.
4. Not to participate in any post season or individual contests as a representative of the Bristol Public Schools without the school's explicit and expressed permission.

The failure of one (1) team member to abide by all of the eligibility rules will result in the forfeiture of all contests for the team while the individual was ineligible.

Students participating in interscholastic athletics assume a special responsibility. They serve as models for much of the student body and are representatives of our school district to other school districts and the communities served by our schools.

Student athletes are expected to behave in a manner that will bring credit to themselves and their schools. It is our expectation that students involved in the athletic program will refrain from smoking and the use of alcohol or any other behavior-altering drug.

Failure to comply with the school's expectations may result in removal from the activity and/or in disciplinary action being taken.

Students who are absent or suspended from school may not participate in an extra-curricular activity. Any student who is not present for a minimum of three periods must receive administrative approval to participate in a co-curricular activity held that day.

Extra-Curricular Activities/Athletics - Change in High School District Residency

When a student under 18 years of age leaves the residency of a legal guardian in one Bristol public high school district to reside with friends or relatives in another Bristol public high school district, having filed forms provided by the Board of Education for that purpose, that student will not be eligible to participate in interscholastic athletics at the receiving school in any sport the student previously participated in at the sending school for three hundred sixty-five (365) calendar days of continuous enrollment from the date of the first allowable play date following the date of enrollment (first day of attending classes) in the receiving school, or the first contest after the date of enrollment, if entry is after the first allowable play date at the receiving school.

Parents/legal guardians authorizing the minor student to change residence (i.e., leave home) will be required to provide the Board of Education with legal documentation, on request, to establish their current legal custody of the minor involved.

Instruction

Extra-Curricular Activities/Athletics - Change in High School District Residency

Students and/or their parents/legal guardians may file a waiver request with the Superintendent of Schools within thirty (30) days of change of residency, seeking exemption from this policy because the change in residency is required for compelling personal reasons unrelated to athletics, such as illness or incapacity of family members. The Superintendent of Schools shall consult with the two high school principals and the Supervisor of Physical Education, Health and Athletics and make a recommendation to the Board regarding the request. Should the Superintendent recommend against the waiver, the student and/or parents/legal guardian may appear before the Board, which shall issue the final decision regarding the requested waiver.

Extra-Curricular Activities/Athletics - High School Request for Pupil Transfer within the Bristol Public School System With No Change in Residency

Any student who is granted an out of area transfer request that results in attendance at the non-resident high school is ineligible for interscholastic athletics for thirty (30) calendar days from the date of the first allowable play date following the date of enrollment (first day of attending classes) in the receiving school, or the first contest after the date of enrollment, if entry is after the first allowable play date in any sport the student participated in at the previous school.

Students and/or their parents legal guardians may file a waiver request with the Superintendent of Schools within thirty (30) days of notification of denial of the out of area request, seeking exemption from this policy because the out of area request is required for compelling personal reasons unrelated to athletics/ such as illness or incapacity of family members. The Superintendent of Schools shall consult with the two high school principals and/or the Supervisor of Physical Education, Health and Athletics and make a recommendation to the Board regarding the request. Should the Superintendent recommend against the waiver, the student and/or parents/legal guardian may appear before the Board, which shall issue the final decision regarding the requested waiver.

Instruction

Extra-Curricular and Co-Curricular Activities

Middle and High School Co-Curricular Eligibility

An activity which occurs outside of the school day as an extension of curricula courses is a co-curricular activity. Students participate in the course during the school day and participation in the co-curricular activity is required as part of the course. This pertains specifically to student participation in band, orchestra and/or choral performances which are required for participation in the course. Students will be allowed to participate in such required performances even when on academic restriction (middle school level) or partial eligibility (high school level) for extra-curricular activities.

Middle School and High School Extra-Curricular Eligibility

Extra curricular eligibility policy pertains to not-for-credit activities which take place outside of the school day. This includes athletic teams, intramurals, clubs, performances in plays, adjudications, community concerts, and any other activity which takes place outside of the school day as a course requirement.

High School Full Extra-Curricular Eligibility

Marking period grades will be used to determine eligibility during the school year. Student eligibility is determined no later than the fourteenth (14) calendar day following the end of the marking period.

In order to be eligible to participate in all aspects of an extra-curricular activity, a student must meet the following criteria:

I. Scholarship

1. A student cannot at any time represent a school unless taking a minimum of five and a half (5.5) academic credits plus $\frac{1}{2}$ physical education credit at the end of the regular marking period next preceding the contest/event.
2. At the end of the previous marking period, the student is eligible when he/she:
 1. Passes all courses OR
 2. Fails one class with a grade no lower than 60 and has a current weighted GPA of 2.0 or higher. The student must achieve a grade of 65 or higher in that failed course by the date of progress reporting of the marking period following the marking period in which the failure occurred.

Instruction

Extra-Curricular and Co-Curricular Activities

Middle and High School Co-Curricular Eligibility

I. Scholarship – con't

3. To be eligible for fall extra-curricular activities, the student must have received a minimum of 6 credits toward graduation by the beginning of the following school year in all full year and second semester courses. However, students entering grade 9 from grade 8 have full eligibility.

II. Student Eligibility

1. The student should be a member of that school in grade 9, 10, 11, 12.
2. The student shall not have reached his or her nineteenth (19) birthday, except that a player who reaches his or her nineteenth (19) birthday on or after July 1, shall be eligible to compete during the ensuing school year if he or she is otherwise eligible (CIAC eligibility regulation Section II B).
3. Any student who has been enrolled in grades 10, 11, 12 inclusive in any school (member or non-member) shall not participate in the same branch of athletics for more than (3) seasons. A student, upon enrolling in grade nine (9) shall have 4 continuous or uninterrupted years to complete his or her athletic eligibility.

Instruction

High School Full Extra-Curricular Eligibility

High School Partial Extra-Curricular Eligibility

A student placed on Partial Extra-Curricular Eligibility would be granted limited participation but will not be able to represent the school in any type of competition, performance, etc. (i.e., athletic, drama, musical etc.).

Partial Extra-Curricular Eligibility will be offered to a student only once per academic year.

To gain Partial Extra -Curricular Eligibility, a student must meet the following criteria:

1. Be carrying a full academic load; the load for all students is a minimum of five and a half (5.5) academic credits plus $\frac{1}{2}$ physical education credit per year.
2. For the first marking period of the school year, a student must not have failed (defined as a grade lower than 65) more than 2 full year or 2 second semester subjects during the previous year.
3. For the current school year, fails (defined as a grade lower than 65) no more than 2 subjects at the end of the previous marking period. In the event that a student fails a first semester course, which cannot be repeated the second semester, the student will be placed on Partial Extra-Curricular Eligibility for the third marking period and must be passing all subjects with a current weighted GPA of 2.0 at the midpoint of the said marking period.
4. The period of Partial Extra-Curricular Eligibility will extend to the date of progress reporting of the marking period following the marking period in which the failure occurred. A student on Partial Extra-Curricular Eligibility must attain a minimum average of "70" in the subject that was failed. Partial Extra-Curricular Eligibility will be extended in the event that Bristol Summer School offerings are not available to make up the academic failure. In the event that Partial Extra-Curricular Eligibility is granted for the first marking period, the student must be passing all subjects with a current weighted GPA of 2.0 by the date of progress reporting of the marking period.
5. Students, who qualify under the Partial Eligibility Rule during a try-out period, may try-out for extracurricular activities, with the understanding that the Partial Eligibility Rule goes into effect immediately should he/she make the cut.

Instruction

High School Full Extra-Curricular Eligibility

6. Any student receiving a grade of "incomplete" shall be placed on Partial Extra-Curricular Eligibility until a grade is submitted by the teacher or by the date of progress reporting of the marking period.
7. Transfer students' grades are interpreted by the standards of the previously attended school.
8. By July 1 of the previous year, be less than nineteen (19) years old for athletic participation. (CIAC Regulation)

Middle School Co-Curricular and Extra-Curricular Eligibility

Middle School Co and Extra-Curricular eligibility is determined by a student's overall performance in all core subjects and all encore subjects. Students are issued a subject and conduct grade for each subject and these grades are considered. Incomplete grades constitute a failing grade of below 65 until incomplete grades are made up.

At the start of each school year, all students attending middle school, who were promoted to the next grade, are eligible for participation in extra-curricular activities for the first trimester. Students who were retained are not eligible for participation in extra-curricular activities for the first trimester. Student eligibility will be reviewed at the conclusion of the first and second trimesters.

All extra-curricular activities occurring outside of the school day are included in these eligibility guidelines (such as sports/intramurals, cheerleading, dances, school organized clubs and/or events, etc.). Band and chorus activities occurring outside of the school day are considered co-curricular activities; students will participate in the school band and/or choral performances required when enrolled in band and/or chorus during the school day. When on academic restriction, students will not participate in band or chorus performances, such as adjudications, community concerts, etc., that are not required as part of enrollment in band or chorus.

Instruction

Middle School Full Extra-Curricular Eligibility

In order to be eligible to participate in all aspects of an extra-curricular activity, a student must meet the following criteria:

1. Scholarship
 - a. At the end of the first and second trimester, the student must pass all 8 subjects with a grade of 65 or higher.
2. Conduct
 - a. At the end of the first and second trimester, a student must have no more than one grade of *X* in conduct.

Middle School Academic Restriction for Extra-Curricular Activities

A student placed on academic restriction will not participate in extra-curricular activities; a student on academic restriction will not be able to represent the school in any type of extra-curricular competition, performance, etc. (for example, sports/intramurals, a school play, adjudications, ensembles).

A student will be placed on academic restriction for the second and/or third trimester when the following occur:

1. Scholarship
 - a. A student fails one or more subjects (grade of 64 or lower) in the first and/or second trimester.

OR
2. Conduct
 - b. A student has more than one grade of *X* in conduct.

A student on academic restriction may not remain in school after the school day ends unless the student is under teacher supervision for make-up work, extra help, or detention.

Academic restriction will be removed upon successful completion of the second and/or third trimester, defined as the student meeting the requirements for full extra-curricular eligibility.

Instruction

Policy adopted: April 5, 1995
Policy revised: August 21, 1996
Policy revised: March 5, 1997
Policy revised: July 1, 1998
Policy revised: June 6, 2001
Policy revised: June 2, 2004
Policy revised: July 8, 2009
Policy revised: August 19, 2009
Policy revised: August 17, 2011
Policy revised: June 5, 2013

BRISTOL PUBLIC SCHOOLS
Bristol, Connecticut

Extra-Curricular Activities/Athletics - High School Request for Pupil Transfer within the Bristol Public School System With No Change in Residency

(Current) Any student who is granted an out of area transfer request that results in attendance at the non-resident high school is ineligible for interscholastic athletics for thirty (30) calendar days from the date of the first allowable play date following the date of enrollment (first day of attending classes) in the receiving school, or the first contest after the date of enrollment, if entry is after the first allowable play date in any sport the student participated in at the previous school.

*(Proposed change from previous paragraph) Any student who is granted an out of area transfer request that results in attendance at the non-resident high school is ineligible for interscholastic athletics for thirty (30) calendar days from the first date **of practice** following the date of enrollment (first day of attending classes) (for students entering over the summer, the 30 days begin on the first day of practice) in the receiving school, or the first contest after the date of enrollment, if entry is after the first allowable play date in any sport the student participated in at the previous school*

Students and/or their parents legal guardians may file a waiver request with the Superintendent of Schools within thirty (30) days of notification of denial of the out of area request, seeking exemption from this policy because the out of area request is required for compelling personal reasons unrelated to athletics/ such as illness or incapacity of family members. The Superintendent of Schools shall consult with the two high school principals and/or the Supervisor of Physical Education, Health and Athletics and make a recommendation to the Board regarding the request. Should the Superintendent recommend against the waiver, the student and/or parents/legal guardian may appear before the Board, which shall issue the final decision regarding the requested waiver.

Eligibility Policy

High School Full Extra-Curricular Eligibility

(Added) Quarter 1, 2 and 3 grades will be used to determine eligibility during the winter and spring seasons. Final end of the year grades, 2nd semester and summer school grades will determine eligibility for the fall season. During the school year, student eligibility and ineligibility status is determined on the day report cards are distributed or on the fourteenth (14) calendar day following the end of the marking period.

In order to be eligible to participate in all aspects of an extra-curricular activity, a student must meet the following criteria:

Fall Season

A student is eligible when he/she:

- Is entering grade 9 from grade 8 OR must have received a minimum of five and a half (5.5) academic credits plus .5 physical education credit from the previous school (Change: year to year/summer school.) (Add: Students attending BTEC or transferring into a Bristol School, may have the .5 physical education credit waived by the building principal)
- Must be enrolled in a minimum of five and a half (5.5) academic credits plus .5 physical education credit during the current school year.
- Passes all courses OR
- Fails one class for the year or second semester with a grade no lower than 60, (Add: not retaken or failed in summer school), and has a weighted (Add: semester two) GPA of 2.0 or higher.
 - If the student retakes the failed course in the fall, the student must achieve a grade of 65 or higher in that failed course by the midterm of the marking period. (Add: Eligibility of these students will be determined on the third school day after the progress reporting period)

If the student does not repeat the failed course, all grades must be a 70 or better at the midterm of the first marking period. (Add: Eligibility of these students will be determined on the third school day after the progress reporting period)

- The student must be a member of the school in grades 9, 10, 11 or 12.
- (Updated: The student shall not have reached his or her twentieth (20th) birthday. A student-athlete will not be allowed to start a season or compete during a season in which his/her twentieth (20th) birthday falls.)

- A student has eight (8) consecutive semesters or four (4) consecutive years of eligibility from the date of entry into the ninth grade to be eligible for interscholastic competition.
- Any student who has been enrolled in grades 10, 11, 12 inclusive in any school (member or non-member) shall not participate in the same branch of athletics for more than (3) seasons. A student, upon enrolling in grade nine (9) shall have 4 continuous or uninterrupted years to complete his or her athletic eligibility.

Winter and Spring Seasons

- At the end of the previous marking period, the student is eligible when he/she:
- Is enrolled in a minimum of five and a half (5.5) academic credits plus ½ physical education credit.
- Passes all courses OR
- Fails one class with a grade no lower than 60 and have a weighted (Added: **quarter**) GPA of 2.0 or higher.
 - To maintain full eligibility the student must achieve a grade of 65 or higher in the failed course on the progress report following the marking period in which the failure occurred.
 - If the student does not repeat the failed course, all grades must be a 70 or better at the progress report following the marking period in which the failure occurred.
 - (Add: Eligibility of these students will be determined on the third school day after the progress reporting period)
- (Add: Students with an incomplete become ineligible the day grades are distributed or on the 14 calendar date after the close of the term. The student then has 10 days to make up the incomplete. If a student does not make up the incomplete within 10 days, the student remains ineligible. A student becomes eligible when the incomplete grade has been resolved within the 10 days.)
- The student should be a member of that school in grade 9, 10, 11, 12.
- (Updated: The student shall not have reached his or her twentieth (20th) birthday. A student-athlete will not be allowed to start a season or compete during a season in which his/her twentieth (20th) birthday falls.)
- A student has eight (8) consecutive semesters or four (4) consecutive years of eligibility from the date of entry into the ninth grade to be eligible for interscholastic competition.
- Any student who has been enrolled in grades 10, 11, 12 inclusive in any school (member or non-member) shall not participate in the same branch of athletics for more than (3) seasons. A student, upon enrolling in grade nine (9) shall have 4 continuous or uninterrupted years to complete his or her athletic eligibility.

High School Partial Extra-Curricular Eligibility

Fall Season

A student placed on Partial Extra-Curricular Eligibility would be granted limited participation but will not be able to represent the school in any type of competition, performance, etc. (i.e., athletic, drama, musical etc.).

Partial Extra-Curricular Eligibility will be offered to a student only once per academic year.

To gain Partial Extra - Curricular Eligibility, a student must meet the following criteria:

- Fails two classes for the year or second semester, (Add: not retaken or failed in summer school.)
- Be carrying a full academic load; the load for all students is a minimum of five and a half (5.5) academic credits plus ½ physical education credit per year.
- The period of Partial Extra-Curricular Eligibility will extend to the progress reporting period of the first quarter.
- To become eligible at the progress reporting period, a student on Partial Extra-Curricular Eligibility must attain a minimum average of (Change: “70” to “65”) in the subject(s) that were failed and be passing all other classes. If the student (Add: does not) or is unable to retake the failed class or classes, the student *must have a 70 in all subjects.* (Remove: with a current weighted GPA of 2.0 at the midpoint of the said marking period) (Add: Eligibility of these students will be determined on the third school day after the progress reporting period)
- Students, who qualify under the Partial Eligibility Rule during a try-out period, may try-out for extracurricular activities, with the understanding that the Partial Eligibility Rule goes into effect immediately should he/she make the cut.
- Transfer students' grades are interpreted by the standards of the previously attended school.
- (Updated: The student shall not have reached his or her twentieth (20th) birthday. A student-athlete will not be allowed to start a season or compete during a season in which his/her twentieth (20th) birthday falls.)
- A student has eight (8) consecutive semesters or four (4) consecutive years of eligibility from the date of entry into the ninth grade to be eligible for interscholastic competition.
- Any student who has been enrolled in grades 10, 11, 12 inclusive in any school (member or non-member) shall not participate in the same branch of athletics for more than (3) seasons. A student, upon enrolling in grade nine (9) shall have 4 continuous or uninterrupted years to complete his or her athletic eligibility.

High School Partial Extra-Curricular Eligibility

Winter and Spring Seasons

A student placed on Partial Extra-Curricular Eligibility would be granted limited participation but will not be able to represent the school in any type of competition, performance, etc. (i.e., athletic, drama, musical etc.).

Partial Extra-Curricular Eligibility will be offered to a student only once per academic year.

To gain Partial Extra -Curricular Eligibility, a student must meet the following criteria:

- Be carrying a full academic load; the load for all students is a minimum of five and a half (5.5) academic credits plus ½ physical education credit per year.
- For the current school year, fails (defined as a grade lower than 65) no more than 2 subjects at the end of the previous marking period. The period of Partial Extra-Curricular Eligibility will extend to the date of progress reporting of the marking period following the marking period in which the failure(s) occurred. A student on Partial Extra-Curricular Eligibility must attain a minimum average of "65" in the subject(s) that were failed and be passing all classes.
- In the event that a student fails a first semester course, which cannot be repeated the second semester, the student will be placed on Partial Extra-Curricular Eligibility for the third marking period and must be passing all subjects with a grade of 70 at the quarter progress report. (Add: Eligibility of these students will be determined on the third school day after the progress reporting period)
- Students, who qualify under the Partial Eligibility Rule during a try-out period, may try-out for extracurricular activities, with the understanding that the Partial Eligibility Rule goes into effect immediately should he/she make the cut.
- Transfer students' grades are interpreted by the standards of the previously attended school.
- (Updated: The student shall not have reached his or her twentieth (20th) birthday. A student-athlete will not be allowed to start a season or compete during a season in which his/her twentieth (20th) birthday falls.)
- A student has eight (8) consecutive semesters or four (4) consecutive years of eligibility from the date of entry into the ninth grade to be eligible for interscholastic competition.
- Any student who has been enrolled in grades 10, 11, 12 inclusive in any school (member or non-member) shall not participate in the same branch of athletics for more than (3) seasons. A student, upon enrolling in grade nine (9) shall have 4 continuous or uninterrupted years to complete his or her athletic eligibility.

AP Physics C Electricity and Magnetism Audit Outline

Primary Textbook: (Every student is provided with a copy)

Halliday, Resnick, and Walker, Fundamentals of Physics, 8th Edition, 2008

Supplementary Textbooks: (Students do not have copies of these, but materials and approaches are used from them)

- Giancoli, Physics, 4th edition
- Sears, Zemansky, Young, University Physics, 5th edition complete
- Crummett, Western, University Physics, Free Copy 1994
- Cutnell, Johnson, Physics, 3rd edition
- Feynman, et al, Feynman Lectures on Physics, Addison Wesley 1970
- E. Mazur, Peer instruction, A User's Manual, Prentice Hall, 1997
- White and Manning, Experimental College Physics, 3rd edition
- Cioffari, Edmunds, Experiments in College Physics, 6th edition
- Any other related texts from undergraduate, and graduate physics courses.

Supplementary Materials:

- Ideas occasionally taken from “The Physics Teacher”, AAPT publication
- The College Board Website
- Hand-outs and materials from College Board seminars including released AP multiple-choice, and free-response questions, and Teacher's guide.
- AP Physics Lab Guide

Audio-Visual/Computer Supplements:

- 6 networked computers in lab run Vernier Logger Pro 3 which is used to make graphs and analyze data.
- “The Mechanical Universe” and “Beyond the Mechanical Universe” video series from Cal. Tech. Videos are shown throughout the year to give historical, and alternate points of view.
- “Frames of Reference” Video
- PhET computer simulations and accompanying inquiry-based exercises.

General Course Description:

- Town has 2 high schools, and AP physics B is currently offered at both. The physics teachers at both schools meet frequently to discuss and share ideas.
- The physics teachers at each school are proposing to implement Physics C at both schools. The course is not currently offered. This document was jointly created by the two physics teachers.
- AP physics is the first physics course taken by students at my school.
- AP Calculus will be a co-requisite for this course, however the concepts of differentiation and integration will be covered by this course within the context of physics applications.
- We have an A/B day Block schedule, with four 85-minute periods a day, and Wednesday classes meet for 79 minutes.
- AP Physics meets every day for the whole year.
- AP Physics C Mechanics will be covered in the fall/winter, and AP Physics C Electricity and Magnetism will be covered in the winter/spring. The pace of the courses will include time for review and exam preparation.
- Labs are done on any day as required by curriculum
- We have a separate physics lab room that is connected to the physics room.
- Homework is typically assigned every night.
- Pacing is calculated from percentages per topic on the course outline in Acorn Book multiplied by the number of class meetings until AP exam in May.
- Due to the length of the class, students are sometimes given time to work together in groups on problems. This use of class time for group work becomes more frequent as the exam date nears. I encourage the students to form study groups outside of class, as an essential way to learn, and also as practice for next year in college. Very often students meet in groups to prepare the night before quizzes. This helps to satisfy the student-centered requirement.
- A few times a year, special homework assignments are given about one week before quiz. Students can gain points on the quiz by doing a certain number of problems. This type of assignment further encourages students to work together.

Physics Laboratory:

Labs generally fall into two categories. Some labs are designed so that the student can discover a physical principle that has not yet been formally introduced to them by the teacher. Other labs verify principles that the student has already been exposed to. Occasionally students go into lab to quickly obtain data for analysis in the classroom. Due to time constraints, and lack of student experience, full-fledged inquiry student-designed labs are not attempted. We do a mixture of “traditional labs” in which students are provided with explicit instructions, (which are still popular in colleges), and more modern “guided inquiry labs” where students have more freedom to determine the exact procedure, and experimental set up. Labs of this type help to satisfy the guided inquiry

and student-centered learning requirements. Due to the A/B block scheduling, we do not have to wait for a lab period. We have the freedom to do labs at any time. However over the semester, we average at least a day a week in lab with hands on experiments. Thus, lab work takes up roughly 20% of our class time. To further enhance the inquiry nature of the course we have begun to insert exercises from the PhET computer simulations available online. These quality simulations provide an excellent opportunity for student centered work. We will select from pre-made “labs” for this purpose, and will add more of our own written exercises in the future.

Since the first version of this Audit, our departments have obtained a class set of Vernier LabQuest hand-held data collection interfaces, assorted physics sensors, and Logger Pro 3 data collection and analysis software. I am ordering additional physics sensors including magnetic field sensors for next year. Finally, the two physics teachers have made a serious effort to pool our lab equipment, thus allowing us to do more lab activities.

- There is a separate lab room, which is connected to the physics room.
- Labs are done on any day as required by the curriculum.
- Students keep a portfolio of completed labs.
- A sample lab is included at the end of this document.

Assessments:

- At least 3 full period tests are given each marking period.
- Tests include problems from previously released AP Physics C exams.
- Open-ended questions, such as those found in Peer Instruction by Eric Mazur are sometimes included on quizzes. This helps to satisfy the student-centered requirement.

AP Physics C Electricity and Magnetism Course Outline:

Unit 1: Static Electricity

Charge and charging, conductors and insulators, conservation of charge
Point charges, Coulomb’s Law and superposition
Electric Fields, superposition, and uniform electric fields
Lines of force, electric flux, Gauss’s Law as the first Maxwell Equation
Electric fields of continuous charge distribution

The typical static demonstrations are done, including pith balls, electroscope, etc...to stimulate class discussion.

Electric potential of point charges, continuous charge distributions, and uniform electric fields

LAB: EQUIPOTENTIAL SURFACES AND LINES OF FORCE (Traditional and inquiry) Students map electric fields by mapping equipotential surfaces, and drawing in lines of force perpendicular to equipotential surfaces. After doing the dipole and parallel plates, students design their own charge configuration and predict the resulting equipotential surfaces and lines of force. The instructor then produces the configuration, and the students experimentally check it the next day.

Capacitance and capacitors
Parallel plate, cylindrical, and spherical capacitor
Dielectrics, polarization, and its effects on capacitance
Energy stored in a capacitor

Inquiry activity: PhET Capacitor simulation and “The Two Plate Special” exercise written by Hewitt/Baird.

Unit 2: Current Electricity

Electric current and potential difference
Ohm’s Law and resistance
Electric energy

LAB: OHM’S LAW (Traditional) Students get practice connecting series circuits, using volt and ammeters, and determine resistance of various resistors.

LAB: RESISTANCE OF WIRES (Traditional) Students analytically determine the resistance of a wire of known length, cross-sectional area and material. Then they measure its resistance as part of a circuit, and compare result to calculation.

LAB: THE ELECTRICAL EQUIVALENCE OF HEAT (Inquiry) Using water in a Styrofoam cup, students are directed to design an experiment to verify the amount of energy dissipated by a resistor.

Unit 3: DC Circuits

Kirchhoff’s Rules
Circuits with resistors
Circuits with resistors and/or capacitors
RC circuits and time constants

LAB: SERIES/PARALLEL CIRCUITS (Traditional) Students connect series and parallel circuits and verify current and voltage relationships discussed in class.

LAB: SERIES/PARALLEL LIGHTBULBS (Inquiry) Students design a series/parallel combination circuit using lightbulbs as resistors, and predict what happens to bulb brightness when each bulb is removed (unscrewed). They then check their results experimentally.

LAB: KIRCHHOFF'S RULES (Inquiry) Students design series/parallel circuits with with more than one emf, and calculate the currents using Kirchhoff's rules. They then connect the circuits in lab and verify their results.

LAB: RC CIRCUITS (Traditional) Attached as sample lab at the end of this document

LAB: WHEATSTONE BRIDGE (Traditional) Students construct wheatstone bridge and measure unknown resistances, including ammeter and voltmeter resistance.

Unit 4: Magnetic Fields

- Magnetism, poles, lines of force, and fields
- Gauss's Law for magnetic fields as Maxwell's second equation (no magnetic monopoles)
- Magnetic forces on moving electric charges
- Magnetic forces and torques on current carrying conductors
- Magnetic fields of current-carrying conductors and the Law of Biot and Savart.
- Ampere's Law as (almost) Maxwell's third equation

LAB: MAPPING MAGNETIC FIELDS (Traditional) Students sprinkle iron filings to investigate the shape of permanent magnets and current-carrying conductors.

LAB: CURRENT BALANCE (Class lab) The current balance is used to determine a value for the permeability of free space.

LAB: AP Physics Lab Guide Lab Ten MAGNETIC FIELDS (Inquiry) Students determine magnetic fields of loops of wires and of the Earth. In addition students determine the magnetic field of a solenoid.

Unit 5: Electromagnetism

- Magnetic flux
- Faraday's Law as Maxwell's fourth equation
- Induced currents and Lenz's Law
- Motional emf
- Self-inductance and inductors
- Circuits with inductors

Lab: TRANSFORMERS (Traditional) Students investigate transformers by performing several short experiments using LEYBOLD-HERAEUS Science Teaching Modules (STM) for Electromagnetism and induction.

Inquiry activity: PhET Faraday's Law simulation and worksheet (to be written next year).

Unit 6: AC circuits and Maxwell's equations

RL circuits

LC circuits

Maxwell's generalization of Ampere's Law and Maxwell's equations as a foundation for electricity and magnetism

LAB: LR, LC, and RLC Circuits: (Traditional) Students examine AC voltage, currents and their phase relationships for various series circuits, including RLC, using an oscilloscope.

Unit 7: Review and Exam Preparation (Student Centered)

Review

Practice and present released exam questions

Students work in pairs to prepare solutions, which are presented to the class. A student-lead discussion of big ideas and a question and answer round follow

Students evaluate their strengths and weaknesses

Sample Lab

RC Circuits*

(Discharge of a Capacitor)

Preceding experiments dealt with circuits in which currents and potential differences did not vary with time except possibly for variations due to changes in resistance with temperature and variations due to changes in the terminal voltages of seats of emf, resulting from polarization. In this experiment the capacitor will be used as a circuit element which will lead to the concept of time varying charges, currents, and potential differences.

As shown in your text, when an uncharged capacitor C is charged through a resistance R by an emf $\mathcal{E}$, the charge on the capacitor at a time t after the initiation of the process is given by the equation:

$$q = c\mathcal{E} \left(1 - e^{-\frac{t}{RC}} \right) \quad (1)$$

Similarly, it is shown that when a capacitor C is discharged through a resistance R , the charge remaining on the capacitor at a time t is:

$$q = q_0 e^{-\frac{t}{RC}} \quad (2)$$

Where q_0 is the initial charge on the capacitor, i.e. when $t = 0$.

Since $C = qV$, equation 2 may be written as:

$$V = \frac{q_0}{C} e^{-\frac{t}{RC}} = V_0 e^{-\frac{t}{RC}}$$

Where V is the potential difference across the cap at a time t and V_0 is the potential difference across when $t = 0$.

There are various ways in which the discharge of a capacitor may be studied. For example, making use of Ohm's Law, one could rewrite the above equation as:

$$i = i_0 e^{-\frac{t}{RC}}$$

One could charge the capacitor and then connect to it, in series, a high resistance and ammeter and observe the current in the circuit as a function of time.

In the present experiment a capacitor will be charged to a known potential difference and then discharged through a high resistance voltmeter connected across its terminals. The

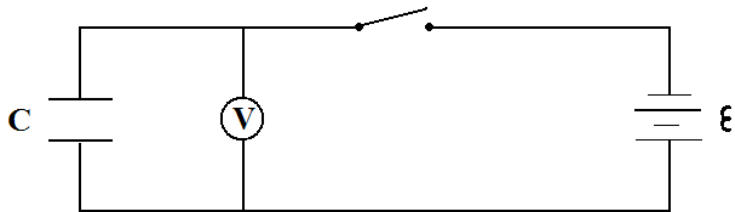
variation of the voltage with time will be observed and plotted. Note that, since a voltmeter is essentially an ammeter with a high resistance in series, this method is basically the same as the first mentioned method.

Apparatus:

- 1 voltmeter
- 1 power supply
- 1 switch
- 6 connection leads
- 1 timer
- 2 capacitors

Procedure:

1. Set the dial on the voltmeter for the 200 VDC. In this setting, its resistance will be sufficiently high so that the capacitor discharges slowly enough to record its values at different times. You will need to determine a method for finding the resistance R of the meter with this setting.
2. Connect the apparatus using one of the capacitors according to the following circuit design.



3. After your instructor has checked the circuit, close the switch and charge the capacitor.
4. Open the switch and, without recording any data, observe the time variation of the potential difference across the capacitor and decide on what time increments should be used so that several readings of the voltage can be made during the discharge of the capacitor.
5. Charge the capacitor again. Open the switch and record V vs. t during the discharge of the capacitor.
6. Plot the data on regular graph paper with t on the x-axis and V on the y-axis.
7. On semi-log paper, plot V vs. t again in the same manner. Your instructor will explain the use of semi-log paper.

8. The time constant of the circuit t_c is defined as the time it takes q (or V) to reach $1/e$ of its maximum value when the capacitor is discharging. Determine the time constant from your graphs. Compare with the value calculated from $t_c = RC$.
9. Show mathematically that the time constant t_c is given by $t_c = RC$.
10. Sketch the curves of q vs. t and i vs. t for the discharge of a capacitor.
11. What quantity is represented by the slope of the q vs. t curve at any instant?
12. The product of the slope of the V vs. t curve, multiplied by C , gives what?
13. Prove that the area under the curve of the i vs. t curve is equal to q_0 . If one measured this area, what additional information would be required to determine the value of an unknown capacitor?
14. Sketch a V vs. t curve for a capacitor during the charging process.
15. Repeat parts 2 to 8 using both capacitors in parallel.
16. Given, $\mathcal{E} - R \frac{dq}{dt} - \frac{q}{C} = 0$ derive equation (1)
17. Given $R \frac{dq}{dt} = -\frac{q}{C}$ derive equation (2)

*from SUNY-ALBANY physics 221 lab manual

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AP Physics C Mechanics Audit Outline

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Physics Laboratory:

Labs generally fall into two categories. Some labs are designed so that the student can discover a physical principle that has not yet been formally introduced to them by the teacher. Other labs verify principles that the student has already been exposed to. Occasionally students go into lab to quickly obtain data for analysis in the classroom.

- There is a separate lab room which is connected to the physics room.
- Labs are done on any day as required by the curriculum.
- Teacher generated lab handouts are used rather than a dedicated lab manual.
- Students keep a portfolio of completed labs.
- A sample lab is included at the end of this document.

Assessments:

- At least 3 full period tests are given each marking period.
- Tests include problems from previously released AP Physics C exams.

Supplementary Materials:

- Ideas occasionally taken from “The Physics Teacher”, AAPT publication
- The College Board Website

- Hand-outs and materials from College Board seminars including released AP multiple-choice, and free-response questions, and Teacher's guide.

Audio-Visual/Computer Supplements:

- 8 computers in lab run PASCO Datastudio and/or Vernier Graphical Analysis (version X) which is used to make graphs and analyze data.
- "The Mechanical Universe" and "Beyond the Mechanical Universe" video series from Cal. Tech. Videos are shown throughout the year to give historical, and alternate points of view.
- "Frames of Reference" Video

General Course Description:

- Town has 2 high schools, and AP physics B is currently offered at both. The physics teachers at both schools meet frequently to discuss and share ideas, and share equipment.
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- AP Physics meets every day for the whole year.
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- A few times a year, special homework assignments are given about one week before quiz. Students can gain points on the quiz by doing a certain number of problems. This type of assignment further encourages students to work together.
- Open-ended questions, such as those found in Peer Instruction by Eric Mazur are sometimes included on quizzes.

AP Physics C Mechanics Course Outline:

Weeks 1 and 2

Introductory items

Kinematics in one dimension, introduce derivative and definite integral

LAB: MEASUREMENT (Hands-on lab) (1 period) Students use ruler, vernier caliper, micrometer to measure various objects and get a feel for the physical meaning of significant figures, and get practice calculating areas and volumes to the correct number of sig. figs.

LAB: FREE Fall (Hands-on lab) (1 period) Students use a spark timer to generate free-fall data. Measurements (vernier caliper) of distance between dots leads to x vs. t (parabolic) and v vs. t (linear) graphs. We verify the kinematics equations with constant acceleration (3 equations) and measure g .

Weeks 2 and 3

Vectors

Projectile motion

Circular kinematics

Relative motion

LAB: PROJECTILE MOTION (Hands-on lab) (.5 period) An air-powered rocket is launched vertically outdoors and time of flight is measured in order for students to determine the rocket's initial launch velocity. Next, the students predict the rocket's range when launched at an angle of 45° . Finally, the rocket is launched at this angle, in order to verify the laws of vectors and kinematics.

Weeks 4 to 6

Newton's Laws

Equilibrium

Non-equilibrium

Multiple bodies

Variable forces

LAB: EQUILIBRIUM (Hands-on lab) (1.5 periods) Students choose collection of three given forces. First they choose 2 givens, and calculate equilibrant force. Graphical (scale vector diagrams) and trigonometric methods are used to calculate the equilibrant force. They then test their results on the force table. Do it again for equilibrant force of all three chosen given forces.

LAB: DISCOVERING NEWTON'S 2ND LAW (Hands-on, discovery) (.5 period) Students measure the time for a cart to roll a given distance from rest when pulled by varying weights hung from a pulley. After cart's acceleration is determined, students plot T vs. a to discover direct proportional relationship.

LAB: APPARENT WEIGHT (hands-on lab) (.5 period) Students stand on a bathroom scale and record scale reading (apparent weight) during various phases of a ride on the school elevator in order to measure the acceleration of the elevator. Graphs of x vs. t and v vs. t and a vs. t are made.

LAB: FRICTION (hands-on open-ended lab) (1 period) Students are given wood block, wood plank (that can be made into an inclined plane), pulley, string, masses, stop-watch, *etc...* and are to determine coefficient of friction between wood block and wood plank.

Weeks 7 and 8

- Work
- Power
- Work-Kinetic energy theorem
- Conservative forces and potential energy
- Non-Conservative forces
- Conservation of energy
- Work done by variable forces, and integration

LAB: DISCOVERING CONSERVATION OF ENERGY (hands-on, discovery lab) (.5 period) Students release pendulum from known heights, and use a photogate to help them determine the bob's velocity at the equilibrium point in order to compare the bob's gravitational potential energy at the release point to its kinetic energy at the equilibrium point.

Weeks 9 and 10

- Center of mass, discrete and continuous bodies
- Momentum and impulse
- Internal and external forces
- Conservation of momentum
- Collisions
- Impulse of variable forces, and integration

LAB: DISCOVERING THAT MOMENTUM IS CONSERVED DURING COLLISIONS (Hands-on, discovery) (.5 period) Two carts of known mass collide on an air track in various ways. Photogates are used to determine the velocity of each cart both before and after the collisions. Students find the vector sum of the carts' momentum before and after the collisions, to discover conservation of momentum.

Weeks 11 to 13

- Uniform circular motion dynamics
- Torque and equilibrium
- Rotational kinematics
- Rotational dynamics, and moments of inertia
- Angular momentum
- Conservation of angular momentum

LAB: CIRCULAR MOTION (hands-on lab) (1 period) Whirl stopper on string with glass tube and masses. Measure period with stopwatch. Compare hanging weight with calculated centripetal force of whirling stopper.

LAB: TORQUE EQUILIBRIUM (hands-on lab) (1 period) Students make see/saw, off center see/saw, and window washer arrangements with meter sticks *etc...* to verify second condition of equilibrium, namely $\sum \tau = 0$.

To be included (open-ended part) Students are given an “altered” meter stick and are to determine mass of meter stick without mass balance.

LAB: ROTATIONAL MOTION (Hands-on lab) (1 period) Lab attached as a sample at the end of this document.

Weeks 14

Kepler's Laws

Newton's Law of universal gravitation

Gravitational fields of extended bodies

Potential energy of a variable force

Weeks 15 and 16

Linear restoring forces

Simple harmonic motion, differential equations

Mechanical waves

LAB: HOOKE'S LAW STATIC MEASUREMENT OF SPRING CONSTANT (hands-on lab) (.5 period) Students do static determination of spring constant by measuring displacements as mass is added to end of spring.

LAB: DYNAMIC MEASUREMENT OF SPRING CONSTANT (hands-on lab) (.5 period) Students measure period of oscillating mass/spring combo. And determine spring constant.

LAB: PENDULUM (Hands-on, open ended lab) (1 period) Students given mass, string, meter stick, stop watch. Student's job is to measure g.

LAB: STANDING WAVES ON STRINGS (hands-on lab) (1 period) Students excite various standing wave modes on a vibrating string by changing the tension in the string (vary hanging weight) and calculate the frequency of vibration.

LAB STANDING WAVES IN TUBES (SPEED OF SOUND) (Hands on) (1 period) Students generate resonant standing waves in a variable height tube using tuning forks of known frequency. They calculate the speed of sound.

Sample Lab

Study of Rotational Motion and Rotational Inertia

Objective: To determine dynamically, the moments of inertia of a ring and disc

Apparatus: Ring, disc, turntable on bearings, cylinder, pulley, small masses, string, stopwatch

Precautions: 1. Make certain that the hub (center) rotates freely.

Introduction:

In the study of mechanics, we started with the basic kinematical concepts of displacement and time, and derived concepts of velocity and acceleration. These, together with the dynamical concepts of force and mass serve well to describe certain domains of the science of motion, particularly linear motion. We now consider the *rotational* motion of rigid objects. To do this we need to describe the kinematics and the dynamics of the motion in an appropriate way. The quantities introduced to describe rotational motion are, in every case, analogous to corresponding concepts in linear motion. These analogies along with their appropriate units and connecting equations are listed in table 1 below:

	Linear quantities	units	Connecting equations	Angular quantities	units
displacement	x	m	$x = r\theta$	θ	rad
velocity	$v = \frac{dx}{dt}$	m/s	$v = r\omega$	$\omega = \frac{d\theta}{dt}$	rad/s
acceleration	$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$	m/s ²	$a = r\alpha$	$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$	rad/s ²
force	F	N		$\tau = r \times F$	mN
Newton's 2 nd Law	$\sum F = ma$			$\sum \tau = I\alpha$	
mass	m	kg		$I = \int r^2 dm$	kgm ²

Table 1

The Exercise:

Our intention is to perform a dynamical determination of the moment of inertia of a disk and a ring analogous to the dynamical determination of mass that we did earlier in the year. The apparatus, illustrated in figure 1, is similar, with the rotating disc apparatus replacing the air track rider and the air track that was used in that earlier experiment. Our procedure will be to determine the angular acceleration and applied torque for various masses. Then by making an appropriate graph, the desired moments of inertia can be determined.

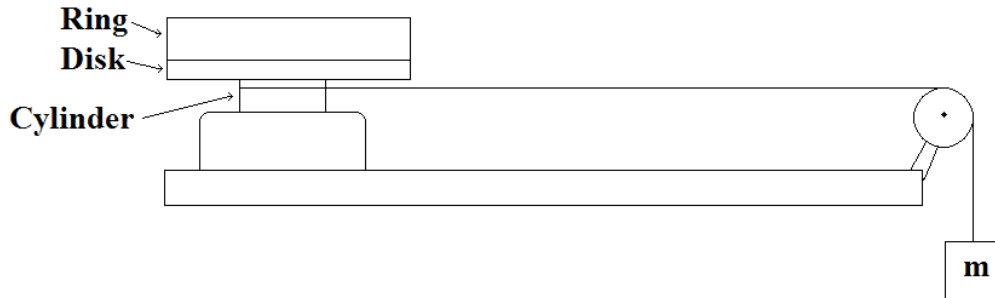


Figure 1.

A constant torque will be applied to the table by the tension in the string and will give the turntable a constant angular acceleration α . By measuring the time it takes hanging mass m to fall a known distance you will actually determine the *linear* acceleration a , of hanging mass m . From this linear acceleration, the angular acceleration α of the turntable can be calculated.

Next, you will carefully determine the torque exerted on the turntable by the tension in the string. Please make an FBD for the hanging mass in the space below, and show a general calculation for the tension in the string (while mass m is accelerating!).

...The space below for hanging mass FBD and tension calculation

By recording data in the manner shown below, the moments of inertia can be determined for (a) Ring and (b) Disc.

Data Tabulation:

Distance hanging mass m falls in each trial _____

Radius of cylinder _____

Mass of disc _____

Mass of ring _____

Radius of disc _____

Inner radius of ring _____

Outer radius of ring _____

Anything else you think you might need!

Hanging mass m (kg)	Time to fall given distance Trial 1 (s)	Time to fall given distance Trial 2 (s)	Time to fall given distance Trial 3 (s)	Time to fall given distance Trial 4 (s)	Time to fall given distance Average (s)

Hanging mass m (kg)	<u>Average</u> time taken for mass to fall given distance (s)	Acceleration of hanging mass (m/s ²)	Tension in string (N)	$\tau = r \times T$ (mN)	$\alpha = \frac{a}{r}$ (rad/s ²)

Instructions for data-taking

1. Mass the ring and disc and measure their radial dimensions. Also measure the radius of the cylinder hub.
2. The empty turntable. Suspend a mass from the string, which passes over the pulley and is connected to the empty turntable cylinder. Making sure the table starts from rest, release the mass and measure the time it takes to fall your chosen given distance. Do several trials for each mass, and use the average value for your calculations. Vary the hanging mass, using a total of 7 or 8 masses to provide your data points.
3. Repeat instruction 2 for the turntable and ring.
4. Repeat instruction 2 for the turntable and disc.

Report

Calculate the moments of inertia of the ring and the disk using the appropriate formulae and the data obtained from instruction 1. Graph the torque versus acceleration (τ vs. α) for the empty turntable, the turntable and ring, and the turntable and disc. Obtain the I 's from the slopes of the graphs. Subtract the empty table's moment of inertia from the ring and table and disc and table results. Compare these values with the theoretical ones, which you calculated earlier.

Show a sample calculation for the tension in the string and the torque on the table.

Show clearly the relationship of the cylinder hub's tangential acceleration to the table's angular acceleration.



AP[®] PHYSICS 1: ALGEBRA-BASED AND AP[®] PHYSICS 2: ALGEBRA-BASED



Course and Exam Description Including the Curriculum Framework

Effective Fall 2014



AP[®] PHYSICS 1:
ALGEBRA-BASED AND
AP[®] PHYSICS 2:
ALGEBRA-BASED

Course and Exam Description

Effective Fall 2014



About the College Board

The College Board is a mission-driven, not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools.

For further information, visit www.collegeboard.org.

AP® Equity and Access Policy

The College Board strongly encourages educators to make equitable access a guiding principle for their AP programs by giving all willing and academically prepared students the opportunity to participate in AP. We encourage the elimination of barriers that restrict access to AP for students from ethnic, racial, and socioeconomic groups that have been traditionally underserved. Schools should make every effort to ensure their AP classes reflect the diversity of their student population. The College Board also believes that all students should have access to academically challenging course work before they enroll in AP classes, which can prepare them for AP success. It is only through a commitment to equitable preparation and access that true equity and excellence can be achieved.

AP Course and Exam Descriptions

AP course and exam descriptions are updated regularly. Please visit AP Central® (apcentral.collegeboard.org) to determine whether a more recent course and exam description PDF is available.

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About AP®

The College Board's Advanced Placement Program® (AP®) enables students to pursue college-level studies while still in high school. Through more than 30 courses, each culminating in a rigorous exam, AP provides willing and academically prepared students with the opportunity to earn college credit and/or advanced placement. Taking AP courses also demonstrates to college admission officers that students have sought out the most rigorous course work available to them.

Each AP course is modeled upon a comparable college course, and college and university faculty play a vital role in ensuring that AP courses align with college-level standards. Talented and dedicated AP teachers help AP students in classrooms around the world develop and apply the content knowledge and skills they will need later in college.

Each AP course concludes with a college-level assessment developed and scored by college and university faculty as well as experienced AP teachers. AP Exams are an essential part of the AP experience, enabling students to demonstrate their mastery of college-level course work. Most four-year colleges and universities in the United States and universities in more than 60 countries recognize AP in the admission process and grant students credit, placement, or both on the basis of successful AP Exam scores. Visit www.collegeboard.org/apcreditpolicy to view AP credit and placement policies at more than 1,000 colleges and universities.

Performing well on an AP Exam means more than just the successful completion of a course; it is a gateway to success in college. Research consistently shows that students who receive a score of 3 or higher on AP Exams typically experience greater academic success in college and have higher graduation rates than their non-AP peers.¹ Additional AP studies are available at www.collegeboard.org/research.

Offering AP Courses and Enrolling Students

This *AP Course and Exam Description* details the essential information required to understand the objectives and expectations of an AP course. The AP Program unequivocally supports the principle that each school implements its own curriculum that will enable students to develop the content knowledge and skills described here.

¹See the following research studies for more details:

Linda Hargrove, Donn Godin, and Barbara Dodd, *College Outcomes Comparisons by AP and Non-AP High School Experiences* (New York: The College Board, 2008).

Chrys Dougherty, Lynn Mellor, and Shuling Jian, *The Relationship Between Advanced Placement and College Graduation* (Austin, Texas: National Center for Educational Accountability, 2006).

Enrolling prepared and motivated students in an AP program requires a concerted effort on the part of administrators, counselors, and teachers. Key to the process is communicating the unique benefits of AP and inspiring students to take AP courses and exams, benefits that include opportunities to:

- Earn credit or placement for qualifying AP Exam grades
- Stand out in the admissions process
- Earn academic scholarships and awards from colleges and universities
- Experience a college-level exam
- Be prepared for college-level course work

The College Board strongly encourages educators to make equitable access a guiding principle for their AP programs by giving all willing and academically prepared students the opportunity to participate in AP. We encourage the elimination of barriers that restrict access to AP for students from ethnic, racial and socioeconomic groups that have been traditionally underserved. Schools should make every effort to ensure their AP classes reflect the diversity of their student population. The College Board also believes that all students should have access to academically challenging course work before they enroll in AP classes, which can prepare them for AP success. It is only through a commitment to equitable preparation and access that true equity and excellence can be achieved.

How AP Courses and Exams Are Developed

AP courses and exams are designed by committees of college faculty and expert AP teachers who ensure that each AP subject reflects and assesses college-level expectations. To find a list of each subject's current AP Development Committee members, please visit press.collegeboard.org/ap/committees. AP Development Committees define the scope and expectations of the course, articulating through a curriculum framework what students should know and be able to do upon completion of the AP course. Their work is informed by data collected from a range of colleges and universities to ensure that AP coursework reflects current scholarship and advances in the discipline.

The AP Development Committees are also responsible for drawing clear and well-articulated connections between the AP course and AP Exam — work that includes designing and approving exam specifications and exam questions. The AP Exam development process is a multiyear endeavor; all AP Exams undergo extensive review, revision, piloting, and analysis to ensure that questions are high quality and fair and that there is an appropriate spread of difficulty across the questions.

Throughout AP course and exam development, the College Board gathers feedback from various stakeholders in both secondary schools and higher education institutions. This feedback is carefully considered to ensure that AP courses and exams are able to provide students with a college-level learning experience and the opportunity to demonstrate their qualifications for advanced placement upon college entrance.

Course Audit

Schools wishing to offer AP courses must participate in the AP Course Audit, a process through which AP teachers' syllabi are reviewed by college faculty. The AP Course Audit was created at the request of College Board members who sought a means for the College Board to provide teachers and administrators with clear guidelines on curricular and resource requirements for AP courses and to help colleges and universities validate courses marked "AP" on students' transcripts. This process ensures that AP teachers' syllabi meet or exceed the curricular and resource expectations that college and secondary school faculty have established for college-level courses. For more information on the AP Course Audit, visit www.collegeboard.com/apcourseaudit.

How AP Exams Are Scored

The exam scoring process, like the course and exam development process, relies on the expertise of both AP teachers and college faculty. While multiple-choice questions are scored by machine, the free-response questions are scored by thousands of college faculty and expert AP teachers at the annual AP Reading. AP Exam Readers are thoroughly trained, and their work is monitored throughout the reading for fairness and consistency. In each subject, a highly respected college faculty member fills the role of Chief Reader, who, with the help of AP Readers in leadership positions, maintains the accuracy of the scoring standards. Scores on the free-response questions are weighted and combined with the results of the computer-scored multiple-choice questions, and this raw score is converted into a composite AP score of 5, 4, 3, 2, or 1.

The score-setting process is both precise and labor intensive, involving numerous psychometric analyses of the results of a specific AP Exam in a specific year and of the particular group of students who took that exam. Additionally, to ensure alignment with college-level standards, part of the score-setting process involves comparing the performance of AP students with the performance of students enrolled in comparable courses in colleges throughout the United States. In general, the AP composite score points are set so that the lowest raw score needed to earn an AP score of 5 is equivalent to the average score among college students earning grades of A in the college course. Similarly, AP Exam scores of 4 are equivalent to college grades of A–, B+, and B. AP Exam scores of 3 are equivalent to college grades of B–, C+, and C.

Using and Interpreting AP Scores

The extensive work done by college faculty and AP teachers in the development of the course and the exam and throughout the scoring process ensures that AP Exam scores accurately represent students' achievement in the equivalent college course. While colleges and universities are responsible for setting their own credit and placement policies, AP scores signify how qualified students are to receive college credit or placement:

AP Score	Qualification
5	Extremely well qualified
4	Well qualified
3	Qualified
2	Possibly qualified
1	No recommendation

Additional Resources

Visit apcentral.collegeboard.org for more information about the AP Program.

About the AP Physics 1 and 2 Courses

This *AP Physics 1: Algebra-Based* and *AP Physics 2: Algebra-Based Course and Exam Description* details the essential information required to understand the objectives and expectations of an AP course. The AP Program unequivocally supports the principle that each school develops and implements its own curriculum that will enable students to develop the content knowledge and skills described here.

The Courses:

Guided by the National Research Council and National Science Foundation, the AP[®] Program collaborated with college and university educators and AP teachers to develop two full-year AP Physics courses — AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based, replacing the former one-year AP Physics B course. The AP Physics 1 and 2 courses focus on the big ideas typically included in the first and second semesters of an algebra-based, introductory college-level physics sequence and provide students with enduring understandings to support future advanced course work in the sciences. Through inquiry-based learning, students will develop critical thinking and reasoning skills, as defined by the AP Science Practices.

Students will cultivate their understanding of physics and science practices as they explore the following topics:

AP Physics 1

- Kinematics
- Dynamics: Newton's laws
- Circular motion and universal law of gravitation
- Simple harmonic motion: simple pendulum and mass-spring systems
- Impulse, linear momentum, and conservation of linear momentum: collisions
- Work, energy, and conservation of energy
- Rotational motion: torque, rotational kinematics and energy, rotational dynamics, and conservation of angular momentum
- Electrostatics: electric charge and electric force
- DC circuits: resistors only
- Mechanical waves and sound

AP Physics 2

- Thermodynamics: laws of thermodynamics, ideal gases, and kinetic theory
- Fluid statics and dynamics
- Electrostatics: electric force, electric field and electric potential
- DC circuits and RC circuits (steady-state only)
- Magnetism and electromagnetic induction
- Geometric and physical optics
- Quantum physics, atomic, and nuclear physics

The Laboratory Requirement

This course requires that 25 percent of the instructional time will be spent in laboratory work, with an emphasis on inquiry-based investigations that provide students with opportunities to demonstrate the foundational physics principles and apply all seven science practices defined in the curriculum framework.

Recommended Prerequisites

The AP Physics 1 course is designed to be taught over the course of a full academic year and may be taken as a first-year physics course with no prior physics course work necessary. Students should have completed geometry and be concurrently taking algebra II, or an equivalent course. Although the Physics 1 course includes basic use of trigonometric functions, this understanding can be gained either in the concurrent math course or in the AP Physics 1 course itself.

The AP Physics 2 course is designed to be taught over the course of a full academic year and should be taken as a second-year course after students have had either AP Physics 1 or a similar introductory course. Students should have taken or be concurrently taking precalculus or an equivalent course.

Curriculum Framework Overview

The *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Curriculum Framework* is structured around the “big ideas” of physics, which encompass core scientific principles, theories, and processes of the discipline. The framework encourages instruction that allows students to make connections across domains through a broader way of thinking about the physical world. Big ideas cut across the traditional physics principles and are supported with enduring understandings, which incorporate the core concepts that students should retain from their learning experiences. See Appendix C to the curriculum framework for a table that illustrates how the foundational physics principles support the development of the following big ideas:

Big idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Big idea 2: Fields existing in space can be used to explain interactions.

Big idea 3: The interactions of an object with other objects can be described by forces.

Big idea 4: Interactions between systems can result in changes in those systems.

Big idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Big idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Big idea 7: The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems

These courses also provide students with opportunities to engage in the AP Science Practices, whereby they establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena. Focusing on these reasoning skills enables teachers to use the principles of scientific inquiry to promote a more engaging and rigorous experience for AP Physics students.

Science practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

Science practice 2: The student can use mathematics appropriately.

Science practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

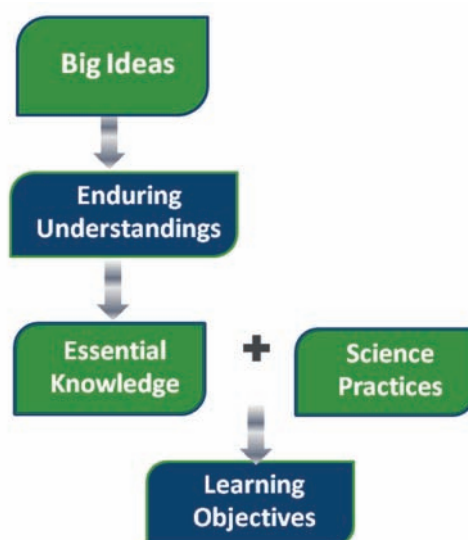
Science practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question.

Science practice 5: The student can perform data analysis and evaluation of evidence.

Science practice 6: The student can work with scientific explanations and theories.

Science practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

In the AP Physics 1 and 2 courses, the content and reasoning skills (science practices) are equally important and are therefore described together in the concept outline to define what a student should *know* and *do* within the context of each course.



Participating in the AP Course Audit

Schools wishing to offer AP courses must participate in the AP Course Audit. Participation in the AP Course Audit requires the online submission of two documents: the AP Course Audit form and the teacher's syllabus. The AP Course Audit form is submitted by the AP teacher and the school principal (or designated administrator) to confirm awareness and understanding of the curricular and resource requirements. The syllabus, detailing how course requirements are met, is submitted by the AP teacher for review by college faculty.

The curricular and resource requirements, derived from the *AP Physics 1: Algebra-Based* and *AP Physics 2: Algebra-Based Curriculum Framework*, are outlined below. Teachers should use these requirements in conjunction with the AP Course Audit resources at www.collegeboard.org/apcourseaudit to support syllabus development. Each of the AP Physics algebra-based courses are the equivalent of a semester college course in algebra-based physics and are designed to be taught over a full academic year to enable AP students to develop deep understanding of the content and to focus on applying their knowledge through inquiry-based investigations.

AP Physics 1 Curricular Requirements

- Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.
- The course design provides opportunities for students to develop understanding of the AP Physics 1 foundational physics principles in the context of the big ideas that organize the curriculum framework.
- Students have opportunities to apply AP Physics 1 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.
- The course provides students with opportunities to apply their knowledge of physics principles to real world questions or scenarios (including societal issues or technological innovations) to help them become scientifically literate citizens.

- Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.
- Students are provided the opportunity to engage in inquiry-based laboratory investigations that support the foundational principles and apply all seven science practices defined in the curriculum framework.
- The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.
- The course provides opportunities for students to develop written and oral scientific argumentation skills.

Resource Requirements

- The school ensures that each student has a college-level physics textbook and reference materials, in print or electronic format, for individual use inside and outside of the classroom.
- The school ensures that students have access to scientific equipment and all necessary materials to conduct college-level physics laboratory investigations as outlined in the teacher's course syllabus.

AP Physics 2 Curricular Requirements

- Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.
- The course design provides opportunities for students to develop understanding of the AP Physics 2 foundational physics principles in the context of the big ideas that organize the curriculum framework.
- Students have opportunities to apply Physics 2 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.
- The course provides students with opportunities to apply their knowledge of physics principles to real world questions or scenarios (including societal issues or technological innovations) to help them become scientifically literate citizens.
- Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.

- Students are provided the opportunity to engage in inquiry-based laboratory investigations that support the foundational principles and apply all seven science practices defined in the curriculum framework.
- The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.
- The course provides opportunities for students to develop written and oral scientific argumentation skills.

Resource Requirements

- The school ensures that each student has a college-level physics textbook and reference materials, in print or electronic format, for individual use inside and outside of the classroom.
- The school ensures that students have access to scientific equipment and all necessary materials to conduct college-level physics laboratory investigations as outlined in the teacher's course syllabus.

AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Curriculum Framework

Introduction

AP Physics 1: Algebra-based and AP Physics 2: Algebra-based are two, full-year AP Physics courses, equivalent to the first and second semesters of a typical introductory, algebra-based college physics course. By limiting the scope of content in each of the courses, this framework gives teachers the time needed to foster greater depth of conceptual understanding through the use of student-centered, inquiry-based instructional practices. Teachers will also have time to cover the concepts and skills students will need to demonstrate in order to earn credit for the introductory algebra-based college physics course.

This framework focuses on the big ideas in an introductory college-level physics sequence and provides students with enduring, conceptual understandings of foundational physics principles. This approach enables students to spend less time on mathematical routines and more time engaged in inquiry-based learning of essential concepts, and it will help them develop the critical thinking and reasoning skills necessary to engage in the science practices used throughout their study of algebra-based AP Physics and subsequent course work in science disciplines.

Having a deep understanding of physics principles implies the ability to reason about physical phenomena using important science process skills such as explaining causal relationships, applying and justifying the use of mathematical routines, designing experiments, analyzing data, and making connections across multiple topics within the course. Therefore, the Curriculum Framework for AP Physics 1: Algebra-based and AP Physics 2: Algebra-based pairs the core essential knowledge with the fundamental scientific reasoning skills necessary for authentic scientific inquiry and engages students at an academic level equivalent to two semesters of a typical college or university algebra-based, introductory physics course sequence. The result will be readiness for the study of advanced topics in subsequent college courses — a goal of every AP course.

The Emphasis on Science Practices

A practice is a way to coordinate knowledge and skills in order to accomplish a goal or task. The science practices enable students to establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena. Because content, inquiry, and reasoning are equally important in AP Physics, each learning objective described in the concept outline combines content with inquiry and reasoning skills described in the science practices.

The science practices that follow the concept outline of this framework capture important aspects of the work that scientists engage in, at the level of competence expected of AP Physics students. AP Physics teachers will see within the learning objectives how these practices are integrated with the course content, and they will be able to design instruction with these practices in mind.

Overview of the Concept Outline

The AP Physics 1: Algebra-based and AP Physics 2: Algebra-based concepts are articulated together in one concept outline, providing the full scope of conceptual understandings a student should acquire by the end of an introductory sequence in college-level, algebra-based physics.

The key concepts and related content that define the AP Physics 1: Algebra-based and AP Physics 2: Algebra-based courses and exams are organized around seven underlying principles called the big ideas, which encompass the core scientific principles, theories, and processes of physics that cut across traditional content boundaries and provide students a broad way of thinking about the physical world. For each big idea, *enduring understandings*, which incorporate the core concepts that students should retain from the learning experience, are also identified.

Each enduring understanding is followed by statements of the *essential knowledge* necessary to support that understanding. Unless otherwise specified, all the details in the outline are required elements of the course and may be needed to successfully meet the learning objectives tested by the AP Physics 1: Algebra-based or AP Physics 2: Algebra-based exams as outlined in the Curriculum Framework. The corresponding *learning objectives* pair the essential knowledge to the appropriate science practice(s).

Learning objectives provide clear and detailed articulation of what students should know and be able to do. Each learning objective is designed to help teachers integrate science practices with specific content, and to provide them with clear information about how students will be expected to demonstrate their knowledge and abilities. These learning objectives fully define what will

be assessed on the AP Physics 1 and AP Physics 2 exams; questions that do not align with one or more learning objectives will not appear on the exam. Learning objectives are numbered to correspond with each Big Idea, Enduring Understanding, and Essential Knowledge. Alignment of the learning objectives to the science practices is denoted in brackets, as shown in this example:

Learning Objective: 1.A.2.1

The student is able to construct representations of the differences between a fundamental particle and a system composed of fundamental particles and to relate this to the properties and scales of the systems being investigated.

[See Science Practices 1.1 and 7.1]

There are instances where the essential knowledge does not have stated learning objectives; this essential knowledge serves as a necessary foundation that will be applied in other learning objectives found either within that same enduring understanding or in multiple enduring understandings throughout the Curriculum Framework. Where these instances occur, a statement will appear as follows:

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

Boundary Statements provide guidance to teachers regarding the content boundaries for the AP Physics 1 and 2 courses. These statements help articulate the contextual differences of how the same big ideas and enduring understandings are applied in each course. Boundary statements are denoted as in the example shown below:

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.



Boundary Statement: AP Physics 2 has learning objectives under this enduring understanding that focus on electric and magnetic forces and other forces arising in the context of interactions introduced in Physics 2, rather than the mechanical systems introduced in Physics 1.

Reading the Concept Outline

Each essential knowledge (EK) statement references the big idea and enduring understanding. This EK statement is under Big Idea 1, Enduring Understanding A and is the fifth EK statement under that enduring understanding.

PHYSICS 1	Essential Knowledge 1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an object.	PHYSICS 2
	Learning Objective 1.A.5.1: The student is able to model verbally or visually the properties of a system based on its substructure and to relate this to changes in the system properties over time as external variables are changed. [See Science Practices 1.1 and 7.1]	
	Learning Objective 1.A.5.2: The student is able to construct representations of how the properties of a system are determined by the interactions of its constituent substructures. [See Science Practices 1.1, 1.4, and 7.1]	PHYSICS 2

Each learning objective integrates the essential knowledge with the science practice(s) and clearly defines what a student should know and be able to do.

Course division of content is indicated by text borders for both essential knowledge statements and learning objectives.

The Concept Outline

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

This big idea collects the properties of matter into one area so that they can be employed in other big ideas. The universe contains fundamental particles with no internal structure such as electrons, and systems built from fundamental particles, such as protons and neutrons. These further combine to form atoms, molecules, and macroscopic systems, all of which have internal structures. A system has various attributes or “properties” that determine how it behaves in different situations. When the properties of the system depend on the internal structure of the system, we must treat it as a system. In other cases, the properties of interest may not depend on the internal structure — in AP Physics we call these *objects*. For example, the free-fall motion of a ball can be understood without consideration of the internal structure of the ball, so in this case the ball can be treated as an object. Objects and systems have properties that determine their interactions with other objects and systems. The choice of modeling something as an object or a system is a fundamental step in determining how to describe and analyze a physical situation.

Enduring Understanding 1.A: The internal structure of a system determines many properties of the system.

In a problem of interest, this enduring understanding distinguishes *systems*, where internal structure exists and may need to be taken into account, from *objects*, where internal structure is not present or can be ignored.

Matter builds from fundamental particles, which are objects that have no internal structure, up to systems such as nuclei, atoms, molecules, and macroscopic objects that do have internal structure. The number and arrangements of atomic constituents cause substances to have different properties. There is much contact with chemistry in this enduring understanding in terms of atomic structure, chemical properties of elements, and the incorporation of concepts leading to the quantum model of the atom: energy states, quantized parameters, and transitions.

PHYSICS 1

Essential Knowledge 1.A.1: A system is an object or a collection of objects. Objects are treated as having no internal structure.

- A collection of particles in which internal interactions change little or not at all, or in which changes in these interactions are irrelevant to the question addressed, can be treated as an object.
- Some elementary particles are fundamental particles (e.g., electrons). Protons and neutrons are composed of fundamental particles (i.e., quarks) and might be treated as either systems or objects, depending on the question being addressed.
- The electric charges on neutrons and protons result from their quark compositions.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

Essential Knowledge 1.A.2: Fundamental particles have no internal structure.

- Electrons, neutrinos, photons, and quarks are examples of fundamental particles.
- Neutrons and protons are composed of quarks.
- All quarks have electric charges, which are fractions of the elementary charge of the electron. Students will not be expected to know specifics of quark charge or quark composition of nucleons.

Learning Objective 1.A.2.1:

The student is able to construct representations of the differences between a fundamental particle and a system composed of fundamental particles and to relate this to the properties and scales of the systems being investigated.

[See **Science Practices 1.1 and 7.1**]

PHYSICS 2

Essential Knowledge 1.A.3: Nuclei have internal structures that determine their properties.

- The number of protons identifies the element.
- The number of neutrons together with the number of protons identifies the isotope.
- There are different types of radioactive emissions from the nucleus.
- The rate of decay of any radioactive isotope is specified by its half-life.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

Essential Knowledge 1.A.4: Atoms have internal structures that determine their properties.

- The number of protons in the nucleus determines the number of electrons in a neutral atom.
- The number and arrangements of electrons cause elements to have different properties.
- The Bohr model based on classical foundations was the historical representation of the atom that led to the description of the hydrogen atom in terms of discrete energy states (represented in energy diagrams by discrete energy levels).
- Discrete energy state transitions lead to spectra.

Learning Objective 1.A.4.1:

The student is able to construct representations of the energy-level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated.

[See **Science Practices 1.1 and 7.1**]

PHYSICS 1

Essential Knowledge 1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an *object*.

PHYSICS 2

Learning Objective 1.A.5.1:

The student is able to model verbally or visually the properties of a system based on its substructure and to relate this to changes in the system properties over time as external variables are changed.

[See **Science Practices 1.1 and 7.1**]

Learning Objective 1.A.5.2:

The student is able to construct representations of how the properties of a system are determined by the interactions of its constituent substructures.

[See **Science Practices 1.1, 1.4, and 7.1**]

PHYSICS 2

Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.

Electric charge is the fundamental property of an object that determines how the object interacts with other electrically charged objects. The interaction of a charged object with a distribution of other charged objects is simplified by the field model, where a distribution of charged objects creates a field at every point and the charged object interacts with the field. There are two types of electric charge, positive and negative. Protons are examples of positively charged objects, and electrons are examples of negatively charged objects. Neutral objects and systems are ones whose net charge is zero. The magnitudes of the charge of a proton and of an electron are equal, and this is the smallest unit of charge that is found in an isolated object. Electric charge is conserved in all known processes and interactions.



Boundary Statement: Full coverage of electrostatics occurs in Physics 2. A basic introduction to the concepts that there are positive and negative charges, and the electrostatic attraction and repulsion between these charges, is included in Physics 1 as well.

PHYSICS 1

Essential Knowledge 1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.

- a. An electrical current is a movement of charge through a conductor.
- b. A circuit is a closed loop of electrical current.

PHYSICS 2

Learning Objective: 1.B.1.1:

The student is able to make claims about natural phenomena based on conservation of electric charge.

[See **Science Practice 6.4**]

Learning Objective: 1.B.1.2:

The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.

[See **Science Practices 6.4 and 7.2**]

PHYSICS 1	Essential Knowledge 1.B.2: There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge. a. Like-charged objects and systems repel, and unlike-charged objects and systems attract. b. Charged objects or systems may attract neutral systems by changing the distribution of charge in the neutral system.	PHYSICS 2
PHYSICS 1	Learning Objective: 1.B.2.1 The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. [See Science Practice 6.2]	
	Learning Objective 1.B.2.2: The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. [See Science Practices 6.4 and 7.2]	
	Learning Objective 1.B.2.3: The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object. [See Science Practice 6.1]	
PHYSICS 1	Essential Knowledge 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge. a. The magnitude of the elementary charge is equal to 1.6×10^{-19} coulombs. b. Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron.	PHYSICS 2
	Learning Objective 1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated. [See Science Practices 1.5, 6.1, and 7.2]	

Enduring Understanding 1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems. Gravitational mass is the property of an object or a system that determines the magnitude of its gravitational interaction with other objects, systems, or gravitational fields. From these definitions, classically, there is no expectation that these quantities would be identical. Einstein's assumption that these two quantities, experimentally verified to be equivalent, are in fact the same, is fundamental to the general theory of relativity (which is not part of this course).

Mass is conserved in any process, such as change of shape, change of state, or dissolution, when it is not converted to energy or when energy is not converted to mass. Mass is a central concept in this course; further discussions of mass are found throughout.

PHYSICS 1

Essential Knowledge 1.C.1: Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems.

Learning Objective 1.C.1.1:

The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.

[See **Science Practice 4.2**]

PHYSICS 1

Essential Knowledge 1.C.2: Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.

- The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field.
- Near the Earth's surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 1

Essential Knowledge 1.C.3: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

Learning Objective 1.C.3.1:

The student is able to design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments.

[See **Science Practice 4.2**]

Essential Knowledge 1.C.4: In certain processes, mass can be converted to energy and energy can be converted to mass according to $E = mc^2$, the equation derived from the theory of special relativity.

Learning Objective 1.C.4.1:

The student is able to articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass–energy.

[See **Science Practice 6.3**]

PHYSICS 2

Enduring Understanding 1.D: Classical mechanics cannot describe all properties of objects.

Physicists developed classical mechanics from the intuitive partition of behavior of nature at the human scale into objects that behaved like particles (e.g., rocks) and systems that behaved like waves (e.g., sound waves). Similarly, in classical mechanics they recognized from experience that the motion of objects would appear differently to observers moving relative to each other but assumed that measurements of elapsed time would not be affected by motion. As physicists in the late 19th and early 20th centuries probed the structure of matter at smaller and smaller scales, they discovered that models of atomic and subatomic behavior based on classical intuitions could not explain the experimental results. Ultimately, new mathematical theories were developed that could predict the outcome of experiments but lacked the intuitive underpinning of the classical view. The mathematics gives unambiguous results, but has no single intuitive reference or analogy that can be described in ordinary language. As a result, the best we can do is to describe certain results of experiments as analogous to classical particle behavior and others as analogous to classical wavelike behavior while recognizing that the underlying nature of the object has no precise analogy in human-scale experience.

During the same period, experimental results and theoretical predictions of results in the study of electromagnetic radiation came into conflict with the classical assumption of a common time for all observers. At relative velocities that are large compared with common experience, the special theory of relativity correctly predicts changes in the observed momentum, length, and elapsed time for objects in relative motion. Because humans have no experience of relative motion at such velocities, we have no intuitive underpinnings to explain this behavior. The physics of large relative velocities will only be treated qualitatively in this course.

Essential Knowledge 1.D.1: Objects classically thought of as particles can exhibit properties of waves.

- a. This wavelike behavior of particles has been observed, e.g., in a double-slit experiment using elementary particles.
- b. The classical models of objects do not describe their wave nature. These models break down when observing objects in small dimensions.

Learning Objective 1.D.1.1:

The student is able to explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.

[See **Science Practice 6.3**]

PHYSICS 2

Essential Knowledge 1.D.2: Certain phenomena classically thought of as waves can exhibit properties of particles.

- a. The classical models of waves do not describe the nature of a photon.
- b. Momentum and energy of a photon can be related to its frequency and wavelength.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Essential Knowledge 1.D.3: Properties of space and time cannot always be treated as absolute.

- a. Relativistic mass–energy equivalence is a reconceptualization of matter and energy as two manifestations of the same underlying entity, fully interconvertible, thereby rendering invalid the classically separate laws of conservation of mass and conservation of energy. Students will not be expected to know apparent mass or rest mass.
- b. Measurements of length and time depend on speed. (Qualitative treatment only.)

Learning Objective 1.D.3.1:

The student is able to articulate the reasons that classical mechanics must be replaced by special relativity to describe the experimental results and theoretical predictions that show that the properties of space and time are not absolute. [Students will be expected to recognize situations in which nonrelativistic classical physics breaks down and to explain how relativity addresses that breakdown, but students will not be expected to know in which of two reference frames a given series of events corresponds to a greater or lesser time interval, or a greater or lesser spatial distance; they will just need to know that observers in the two reference frames can “disagree” about some time and distance intervals.] [See **Science Practices 6.3 and 7.1**]

Enduring Understanding 1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.

Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material. Some of the most important fundamental characteristics of matter and space are identified here and employed in other big ideas.

Matter has properties called density, resistivity, and thermal conductivity that are used when discussing thermodynamics, fluids, electric current, and transfer of thermal energy. The values of these quantities depend upon the molecular and atomic structure of the material. Matter and space also have properties called electric permittivity and magnetic permeability. The permittivity and the permeability of free space are constants that appear in physical relationships and in the relationship for the speed of electromagnetic radiation in a vacuum.

The electric permittivity and the magnetic permeability of a material both depend upon the material's structure at the atomic level.

Electric dipole moments (as treated in Enduring Understanding 2.C) and magnetic dipole moments are other properties of matter. A separated pair of positively and negatively charged objects is an example of an electric dipole. A current loop is an example of a magnetic dipole.

Essential Knowledge 1.E.1: Matter has a property called density.	PHYSICS 2
Learning Objective 1.E.1.1: The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. [See Science Practices 4.2 and 6.4]	
Learning Objective 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [See Science Practices 4.1 and 6.4]	
PHYSICS 1 Essential Knowledge 1.E.2: Matter has a property called resistivity. - The resistivity of a material depends on its molecular and atomic structure. - The resistivity depends on the temperature of the material.	PHYSICS 2
Learning Objective 1.E.2.1: The student is able to choose and justify the selection of data needed to determine resistivity for a given material. [See Science Practice 4.1]	
Essential Knowledge 1.E.3: Matter has a property called thermal conductivity. The thermal conductivity is the measure of a material's ability to transfer thermal energy.	PHYSICS 2
Learning Objective 1.E.3.1: The student is able to design an experiment and analyze data from it to examine thermal conductivity. [See Science Practices 4.1, 4.2, and 5.1]	

Essential Knowledge 1.E.4: Matter has a property called electric permittivity.

- a. Free space has a constant value of the permittivity that appears in physical relationships.
- b. The permittivity of matter has a value different from that of free space.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Essential Knowledge 1.E.5: Matter has a property called magnetic permeability.

- a. Free space has a constant value of the permeability that appears in physical relationships.
- b. The permeability of matter has a value different from that of free space.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Essential Knowledge 1.E.6: Matter has a property called magnetic dipole moment.

- a. Magnetic dipole moment is a fundamental source of magnetic behavior of matter and an intrinsic property of some fundamental particles such as the electron.
- b. Permanent magnetism or induced magnetism of matter is a system property resulting from the alignment of magnetic dipole moments within the system.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Big Idea 2: Fields existing in space can be used to explain interactions.

All of the fundamental forces, including the gravitational force and the electric and magnetic forces, are exerted “at a distance”; the two objects involved in the interaction do not “physically touch” each other. To understand and calculate such forces, it is often useful to model them in terms of fields, which associate a value of some quantity with every point in space. Forces are vectors and so the associated fields are also vectors, having a magnitude and direction assigned to each point in space. A field model is also useful for describing how scalar quantities, for instance, temperature and pressure, vary with position. In general, a field created by an array of “sources” can be calculated by combining the fields created by the individual source objects. This is known as the principle of superposition. For a gravitational field the source is an object with mass. For an electric field the source is an object with electric charge. For a magnetic field the source is a magnet or a moving object with electric charge. Visual representations are extensively used by physicists in the analysis of many situations. A broadly used example across many applications involving fields is a map of isolines connecting points of equal value for some quantity related to a field, such as topographical maps that display lines of approximately equal gravitational potential.

Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.

All fundamental forces, including gravitational force, electric force, and magnetic force, are exerted by one object on another object at a distance; this means that the two objects involved in the interaction do not physically touch each other. To understand and calculate such forces, it is often useful to model them in terms of fields. Forces are vectors, and the associated fields are also vectors, having a magnitude and direction assigned to each point in space. A field model is also useful for describing how scalar quantities, such as temperature and pressure, vary with position. In general, the field created by an array of sources, such as objects with electric charge, can be calculated by combining the fields created by the individual source objects. This is known as the principle of superposition.



Boundary Statement: Physics 1 treats gravitational fields; Physics 2 treats electric and magnetic fields.

PHYSICS 1

Essential Knowledge 2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.

- Vector fields are represented by field vectors indicating direction and magnitude.
- When more than one source object with mass or electric charge is present, the field value can be determined by vector addition.
- Conversely, a known vector field can be used to make inferences about the number, relative size, and location of sources.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Essential Knowledge 2.A.2: A scalar field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a scalar. In Physics 2, this should include electric potential.

- Scalar fields are represented by field values.
- When more than one source object with mass or charge is present, the scalar field value can be determined by scalar addition.
- Conversely, a known scalar field can be used to make inferences about the number, relative size, and location of sources.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 2

Enduring Understanding 2.B: A gravitational field is caused by an object with mass.

The gravitational field is the field most accessible to students. The effect of a gravitational field $\vec{g}$ on an object with mass m positioned in the field is a force of magnitude mg that points in the direction of the field. The gravitational field can be represented mathematically. The gravitational field at a point in space due to a spherical object with mass M is a vector whose magnitude is equal to the gravitational force per unit of mass placed at that point. The direction of the field at the point is toward the center of mass of the source object.

The magnitude of the field outside the object is equal to $G \frac{M}{r^2}$, where r is the distance between the center of mass of the object and the point of interest and G is a constant. As with any vector field, a gravitational field can be represented by a drawing that shows arrows at points that are uniformly distributed in space.

PHYSICS 1

Essential Knowledge 2.B.1: A gravitational field $\vec{g}$ at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.

- On Earth, this gravitational force is called weight.
- The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force.
- If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location.

Learning Objective 2.B.1.1:

The student is able to apply $\vec{F} = m\vec{g}$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.

[See **Science Practices 2.2 and 7.2**]

Essential Knowledge 2.B.2: The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object.

- The gravitational field caused by a spherically symmetric object is a vector whose magnitude outside the object is equal to $G \frac{M}{r^2}$.
- Only spherically symmetric objects will be considered as sources of the gravitational field.

Learning Objective 2.B.2.1:

The student is able to apply $g = G \frac{M}{r^2}$ to calculate the gravitational field due to an object with mass M , where the field is a vector directed toward the center of the object of mass M .

[See **Science Practice 2.2**]

Learning Objective 2.B.2.2:

The student is able to approximate a numerical value of the gravitational field (g) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects.

[See **Science Practice 2.2**]

Enduring Understanding 2.C: An electric field is caused by an object with electric charge.

Coulomb's law of electric force describes the interaction at a distance between two electrically charged objects. By contrast, the electric field serves as the intermediary in the interaction of two objects or systems that have the property of electric charge. In the field view, charged source objects create an electric field. The magnitude and direction of the electric field at a given location are due to the vector sum of the fields created by each of the charged objects that are the source of the field. Another charged object placed at a given location in the field experiences an electric force. The force depends on the charge of the object and the magnitude and direction of the electric field at that location. The concept of the electric field greatly facilitates the description of electrical interactions between multiple-point charges or continuous distributions of charge. In this course, students should be familiar with graphical and mathematical representations of the electric field due to one or more point charges including the field of an electric dipole, the field outside a spherically symmetric charged object, and the uniform field between the plates when far from the edges of oppositely charged parallel plates. Students should be able to use these representations to calculate the direction and magnitude of

the force on a small charged object due to such electric fields. Electric field representations are to be vectors and not lines.

Essential Knowledge 2.C.1: The magnitude of the electric force F exerted on an object with electric charge q by an electric field $\vec{E}$ is $\vec{F} = q\vec{E}$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

PHYSICS 2

Learning Objective 2.C.1.1:

The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 2.C.1.2:

The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.

[See **Science Practice 2.2**]

Essential Knowledge 2.C.2: The magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field. This includes positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

PHYSICS 2

Learning Objective 2.C.2.1:

The student is able to qualitatively and semiquantitatively apply the vector relationship between the electric field and the net electric charge creating that field.

[See **Science Practices 2.2 and 6.4**]

Essential Knowledge 2.C.3: The electric field outside a spherically symmetric charged object is radial and its magnitude varies as the inverse square of the radial distance from the center of that object. Electric field lines are not in the curriculum. Students will be expected to rely only on the rough intuitive sense underlying field lines, wherein the field is viewed as analogous to something emanating uniformly from a source.

- a. The inverse square relation known as Coulomb's law gives the magnitude of the electric field at a distance r from the center of a source object of electric charge Q as

$$|E| = \frac{1}{4\pi\epsilon_0} \frac{|Q|}{r^2}.$$

- b. This relation is based on a model of the space surrounding a charged source object by considering the radial dependence of the area of the surface of a sphere centered on the source object.

Learning Objective 2.C.3.1:

The student is able to explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object.

[See **Science Practice 6.2**]

Essential Knowledge 2.C.4: The electric field around dipoles and other systems of electrically charged objects (that can be modeled as point objects) is found by vector addition of the field of each individual object. Electric dipoles are treated qualitatively in this course as a teaching analogy to facilitate student understanding of magnetic dipoles.

- a. When an object is small compared to the distances involved in the problem, or when a larger object is being modeled as a large number of very small constituent particles, these can be modeled as charged objects of negligible size, or “point charges.”
- b. The expression for the electric field due to a point charge can be used to determine the electric field, either qualitatively or quantitatively, around a simple, highly symmetric distribution of point charges.

Learning Objective 2.C.4.1:

The student is able to distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semiquantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field.

[See **Science Practices 2.2, 6.4, and 7.2**]

Learning Objective 2.C.4.2:

The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points.

[See **Science Practices 1.4 and 2.2**]

Essential Knowledge 2.C.5: Between two oppositely charged parallel plates with uniformly distributed electric charge, at points far from the edges of the plates, the electric field is perpendicular to the plates and is constant in both magnitude and direction.

Learning Objective 2.C.5.1:

The student is able to create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs and is able to recognize that the assumption of uniform field is not appropriate near edges of plates.

[See **Science Practices 1.1 and 2.2**]

Learning Objective 2.C.5.2:

The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.

[See **Science Practice 2.2**]

Learning Objective 2.C.5.3:

The student is able to represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in the Earth's gravitational field.

[See **Science Practices 1.1, 2.2, and 7.1**]

Enduring Understanding 2.D: A magnetic field is caused by a magnet or a moving electrically charged object. Magnetic fields observed in nature always seem to be produced either by moving charged objects or by magnetic dipoles or combinations of dipoles and never by single poles.

Knowledge of the properties and sources of magnetic fields is necessary in other big ideas dealing with magnetism. This knowledge is critical to student understanding of areas such as geophysical processes and medical applications. Students also should know that magnetic fields observed in nature always seem to be caused by dipoles or combinations of dipoles and never by single poles. A magnetic dipole can be modeled as a current in a loop. A single magnetic pole (a magnetic monopole like an isolated north pole of a magnet) has never been observed in nature.

Representations of these fields are important to the skills that students need to develop in the course. The pattern of magnetic field vectors tangent to concentric circles around a current-carrying wire and the dipole pattern of field vectors around a bar magnet are needed representations.

Magnetic materials contain magnetic domains that are themselves little magnets. Representations can be drawn of the atomic-scale structure of ferromagnetic materials, such as arrows or smaller bar magnets, which indicate the directional nature of magnets even at these small scales. These magnetic moments lead to discussions of important modern applications such as magnetic storage media.

Essential Knowledge 2.D.1: The magnetic field exerts a force on a moving electrically charged object. That magnetic force is perpendicular to the direction of velocity of the object and to the magnetic field and is proportional to the magnitude of the charge, the magnitude of the velocity, and the magnitude of the magnetic field. It also depends on the angle between the velocity and the magnetic field vectors. Treatment is quantitative for angles of 0° , 90° , or 180° and qualitative for other angles.

Learning Objective 2.D.1.1:

The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field.
[See **Science Practice 2.2**]

PHYSICS 2

Essential Knowledge 2.D.2: The magnetic field vectors around a straight wire that carries electric current are tangent to concentric circles centered on that wire. The field has no component toward the current-carrying wire.

- The magnitude of the magnetic field is proportional to the magnitude of the current in a long straight wire.
- The magnitude of the field varies inversely with distance from the wire, and the direction of the field can be determined by a right-hand rule.

Learning Objective 2.D.2.1:

The student is able to create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires.
[See **Science Practice 1.1**]

PHYSICS 2

Essential Knowledge 2.D.3: A magnetic dipole placed in a magnetic field, such as the ones created by a magnet or the Earth, will tend to align with the magnetic field vector.

- a. A simple magnetic dipole can be modeled by a current in a loop. The dipole is represented by a vector pointing through the loop in the direction of the field produced by the current as given by the right-hand rule.
- b. A compass needle is a permanent magnetic dipole. Iron filings in a magnetic field become induced magnetic dipoles.
- c. All magnets produce a magnetic field. Examples should include magnetic field pattern of a bar magnet as detected by iron filings or small compasses.
- d. Earth has a magnetic field.

Learning Objective 2.D.3.1:

The student is able to describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet.

[See **Science Practice 1.2**]

Essential Knowledge 2.D.4: Ferromagnetic materials contain magnetic domains that are themselves magnets.

- a. Magnetic domains can be aligned by external magnetic fields or can spontaneously align.
- b. Each magnetic domain has its own internal magnetic field, so there is no beginning or end to the magnetic field — it is a continuous loop.
- c. If a bar magnet is broken in half, both halves are magnetic dipoles in themselves; there is no magnetic north pole found isolated from a south pole.

Learning Objective 2.D.4.1:

The student is able to use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material.

[See **Science Practice 1.4**]

Enduring Understanding 2.E: Physicists often construct a map of isolines connecting points of equal value for some quantity related to a field and use these maps to help visualize the field.

When visualizing a scalar field, it is useful to construct a set of contour lines connecting points at which the field has the same (constant) value. A good example is the set of contour lines (gravitational equipotentials) on which the gravitational potential energy per unit mass has a constant value. Such equipotential lines can be constructed using the electric potential and can also be associated with temperature and other scalar fields. When considering equipotential lines, the associated vector field (such as the electric field) is always perpendicular to the equipotential lines. When not provided with a diagram of field vectors, students will be expected to draw accurate equipotential lines ONLY for spherically symmetric sources and for sources that create approximately uniform fields.

Essential Knowledge 2.E.1: Isolines on a topographic (elevation) map describe lines of approximately equal gravitational potential energy per unit mass (gravitational equipotential). As the distance between two different isolines decreases, the steepness of the surface increases. [Contour lines on topographic maps are useful teaching tools for introducing the concept of equipotential lines. Students are encouraged to use the analogy in their answers when explaining gravitational and electrical potential and potential differences.]

Learning Objective 2.E.1.1:

The student is able to construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential.

[See **Science Practices 1.4, 6.4, and 7.2**]

Essential Knowledge 2.E.2: Isolines in a region where an electric field exists represent lines of equal electric potential referred to as equipotential lines.

- An isoline map of electric potential can be constructed from an electric field vector map, using the fact that the isolines are perpendicular to the electric field vectors.
- Since the electric potential has the same value along an isoline, there can be no component of the electric field along the isoline.

Learning Objective 2.E.2.1:

The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 2.E.2.2:

The student is able to predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 2.E.2.3:

The student is able to qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects.

[See **Science Practice 1.4**]

Essential Knowledge 2.E.3: The average value of the electric field in a region equals the change in electric potential across that region divided by the change in position (displacement) in the relevant direction.

Learning Objective 2.E.3.1:

The student is able to apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated.

[See **Science Practice 2.2**]

Learning Objective 2.E.3.2:

The student is able to apply the concept of the isoline representation of electric potential for a given electric charge distribution to predict the average value of the electric field in the region.

[See **Science Practices 1.4 and 6.4**]

Big Idea 3: The interactions of an object with other objects can be described by forces.

An object either has no internal structure or can be analyzed without reference to its internal structure. An interaction between two objects causes changes in the translational and/or rotational motion of each object. When more than one interaction is involved, an object's change in motion is determined by the combination of interactions (the net force). We know of three fundamental interactions or forces in nature: the gravitational force, the electroweak force, and the strong force. The electroweak force unifies the electromagnetic force and the weak force. These two aspects of the electroweak force dominate at different scales, so are discussed separately. These fundamental forces are dominant at different length scales, and all other known “forces” are manifestations of one or the other of these fundamental interactions. The fundamental forces determine both the structure of objects and the motion of objects, from the very small molecular scale (micro and molecular machines and chemical reactions), to the motion of everyday objects such as automobiles and wind turbines, to the motion of tectonic plates, to the motion of objects and systems at the cosmological scale.

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.

The description of motion, including such quantities as position, velocity, or acceleration, depends on the observer, specifically on the reference frame. When the interactions of objects are considered, we only consider the observers in inertial reference frames. In such reference frames, an object that does not interact with any other objects moves at constant velocity. In inertial reference frames, forces are detected by their influence on the motion (specifically the velocity) of an object. So force, like velocity, is a vector quantity. A force vector has magnitude and direction. When multiple forces are exerted on an object, the vector sum of these forces, referred to as the net force, causes a change in the motion of the object. The acceleration of the object is proportional to the net force. If a component of the acceleration is observed to be zero, then the sum of the corresponding force components must be zero. If one object exerts a force on a second object, the second object always exerts a force of equal magnitude but opposite direction on the first object. These two forces are known as an action-reaction pair.



Boundary Statement: AP Physics 2 has learning objectives under this enduring understanding that focus on electric and magnetic forces and other forces arising in the context of interactions introduced in Physics 2, rather than the mechanical systems introduced in Physics 1.

Essential Knowledge 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.

- Displacement, velocity, and acceleration are all vector quantities.
- Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
- A choice of reference frame determines the direction and the magnitude of each of these quantities.

Learning Objective 3.A.1.1:

The student is able to express the motion of an object using narrative, mathematical, and graphical representations.

[See **Science Practices 1.5, 2.1, and 2.2**]

Learning Objective 3.A.1.2:

The student is able to design an experimental investigation of the motion of an object.

[See **Science Practice 4.2**]

Learning Objective 3.A.1.3:

The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.

[See **Science Practice 5.1**]

Essential Knowledge 3.A.2: Forces are described by vectors.

- Forces are detected by their influence on the motion of an object.
- Forces have magnitude and direction.

Learning Objective 3.A.2.1:

The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

[See **Science Practice 1.1**]

PHYSICS 1	Essential Knowledge 3.A.3: A force exerted on an object is always due to the interaction of that object with another object. a. An object cannot exert a force on itself. b. Even though an object is at rest, there may be forces exerted on that object by other objects. c. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.	PHYSICS 2
	Learning Objective 3.A.3.1: The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. [See Science Practices 6.4 and 7.2]	
	Learning Objective 3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself. [See Science Practice 6.1]	PHYSICS 2
	Learning Objective 3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force. [See Science Practice 1.4]	
	Learning Objective 3.A.3.4: The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge. [See Science Practices 6.1 and 6.4]	

Essential Knowledge 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

Learning Objective 3.A.4.1:

The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.

[See **Science Practices 1.4 and 6.2**]

Learning Objective 3.A.4.2:

The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 3.A.4.3:

The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces.

[See **Science Practice 1.4**]

Enduring Understanding 3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$.

Newton’s second law describes the acceleration when one or more forces are exerted on an object. The object’s acceleration also depends on its inertial mass. Newton’s second law is easier to appreciate when the law is written as $\vec{a} = \frac{\Sigma \vec{F}}{m}$, which underscores the cause–effect relationship. In a free-body diagram, the choice of appropriate axes (usually one axis parallel to the direction in which the object will accelerate) and the resolution of forces into components along the chosen set of axes are essential parts of the process of analysis. The set of component forces along an axis corresponds to the list of forces that are combined to cause acceleration along that axis. Constant forces will yield a constant acceleration, but restoring forces, proportional to the displacement of an object, cause oscillatory motion. In this course, the oscillatory solution should be the result of an experiment, rather than the solution of the differential equation.



Boundary Statement: AP Physics 2 contains learning objectives under this enduring understanding that focus on electric and magnetic forces and other forces arising in the context of interactions introduced in Physics 2, rather than the mechanical systems introduced in Physics 1.

PHYSICS 1	Essential Knowledge 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.	PHYSICS 2
	Learning Objective 3.B.1.1: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. [See Science Practices 6.4 and 7.2]	
	Learning Objective 3.B.1.2: The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. [See Science Practices 4.2 and 5.1]	
	Learning Objective 3.B.1.3: The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See Science Practices 1.5 and 2.2]	PHYSICS 2
	Learning Objective 3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [See Science Practices 6.4 and 7.2]	

Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

- a. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
- b. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
- c. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

Learning Objective 3.B.2.1:

The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

[See **Science Practices 1.1, 1.4, and 2.2**]

Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum and mass-spring oscillator.

- For a spring that exerts a linear restoring force, the period of a mass-spring oscillator increases with mass and decreases with spring stiffness.
- For a simple pendulum, the period increases with the length of the pendulum and decreases with the magnitude of the gravitational field.
- Minima, maxima, and zeros of position, velocity, and acceleration are features of harmonic motion. Students should be able to calculate force and acceleration for any given displacement for an object oscillating on a spring.

Learning Objective 3.B.3.1:

The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 3.B.3.2:

The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.

[See **Science Practice 4.2**]

Learning Objective 3.B.3.3:

The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.

[See **Science Practices 2.2 and 5.1**]

Learning Objective 3.B.3.4:

The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.

[See **Science Practices 2.2 and 6.2**]

Enduring Understanding 3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.

In Big Idea 3, the behavior of an object is analyzed without reference to the internal structure of the object. Internal structure is included in Big Idea 4. There are a small number of forces that occur in nature, and the macroscopic ones are considered here. The identification of forces is a key step in the analysis of mechanical systems.

Gravitational forces, electric forces, and magnetic forces between objects are all evident on the macroscopic scale. The gravitational force is a weaker force than the electric or magnetic force. However, on the larger scale, the gravitational force dominates. Electric forces are dominant in determining the properties of the objects in our everyday experience. However, the many electrically charged particles that interact make the treatment of this everyday force very complex. Introducing new concepts such as the frictional force as averages over the many particles reduces the complexity. Contact forces (e.g., frictional force, buoyant force) result from the interaction of one object touching another object and are ultimately due to microscopic electric forces. The frictional force is due to the interaction between surfaces at rest or in relative motion. Buoyant force is caused by the difference in pressure, or force per unit area, exerted on the different surfaces of the object. It is important for students to study each of these forces and to use free-body diagrams to analyze the interactions between objects.

Essential Knowledge 3.C.1: Gravitational force describes the interaction of one object that has mass with another object that has mass.

- The gravitational force is always attractive.
- The magnitude of force between two spherically symmetric objects of mass m_1 and m_2 is $\frac{Gm_1m_2}{r^2}$ where r is the center-to-center distance between the objects.
- In a narrow range of heights above the Earth's surface, the local gravitational field, g , is approximately constant.

Learning Objective 3.C.1.1:

The student is able to use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion.

[See **Science Practice 2.2**]

Learning Objective 3.C.1.2:

The student is able to use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1).

[See **Science Practice 2.2**]

Essential Knowledge 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.

- a. Electric forces dominate the properties of the objects in our everyday experiences. However, the large number of particle interactions that occur make it more convenient to treat everyday forces in terms of nonfundamental forces called contact forces, such as normal force, friction, and tension.
- b. Electric forces may be attractive or repulsive, depending upon the charges on the objects involved.

Learning Objective 3.C.2.1:

The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges (interactions between collections of electric point charges are not covered in Physics 1 and instead are restricted to Physics 2).

[See **Science Practices 2.2 and 6.4**]

Learning Objective 3.C.2.2:

The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.

[See **Science Practice 7.2**]

Learning Objective 3.C.2.3:

The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2 to 4 point charges, though more are permitted in situations of high symmetry).

[See **Science Practice 2.2**]

Essential Knowledge 3.C.3: A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.

- Magnetic dipoles have north and south polarity.
- The magnetic dipole moment of an object has the tail of the magnetic dipole moment vector at the south end of the object and the head of the vector at the north end of the object.
- In the presence of an external magnetic field, the magnetic dipole moment vector will align with the external magnetic field.
- The force exerted on a moving charged object is perpendicular to both the magnetic field and the velocity of the charge and is described by a right-hand rule.

Learning Objective 3.C.3.1:

The **student** is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.

[See **Science Practice 1.4**]

Learning Objective 3.C.3.2:

The student is able to plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion.

[See **Science Practices 4.2 and 5.1**]

PHYSICS 1

Essential Knowledge 3.C.4: Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).

PHYSICS 2

Learning Objective 3.C.4.1:

The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [See **Science Practice 6.1**]

Learning Objective 3.C.4.2:

The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [See **Science Practice 6.2**]

Enduring Understanding 3.D: A force exerted on an object can change the momentum of the object.

The momentum of an object can only change if there is a net force exerted on the object by other objects. Classically, the change in momentum of the object is the product of the average net force on the object and the time interval during which the force is exerted. This product is a vector, called the impulse, and the direction of the impulse is the direction of the change in momentum. The magnitude of the impulse is the area under the force-time curve, which reduces to the product of force and time in the case of a constant force.

PHYSICS 1

Essential Knowledge 3.D.1: The change in momentum of an object is a vector in the direction of the net force exerted on the object.

Learning Objective 3.D.1.1:

The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force. [See **Science Practice 4.1**]

Essential Knowledge 3.D.2: The change in momentum of an object occurs over a time interval.

- The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object).
- The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.

Learning Objective 3.D.2.1:

The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.

[See **Science Practice 2.1**]

Learning Objective 3.D.2.2:

The student is able to predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.

[See **Science Practice 6.4**]

Learning Objective 3.D.2.3:

The student is able to analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.

[See **Science Practice 5.1**]

Learning Objective 3.D.2.4:

The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.

[See **Science Practice 4.2**]

Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.

A net force exerted on an object causes an acceleration of the object, which produces a change in the component of the velocity in the direction of the force. If there is a component of the force in the direction of the object's displacement, the kinetic energy of the object will change. The interaction transfers kinetic energy to or from the object. Only the component of the velocity in the direction of the force is involved in this transfer of kinetic energy. Thus, only the force component in the direction of the object's motion transfers kinetic energy. The amount of energy transferred during a given displacement depends on the

magnitude of the force, the magnitude of the displacement, and the relative direction of force and displacement of the object. Since objects have no internal structure, an isolated object can only have kinetic energy.

PHYSICS 1

Essential Knowledge 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted.

- a. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object.
- b. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to the displacement.
- c. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion.

Learning Objective 3.E.1.1:

The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 3.E.1.2:

The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged.

[See **Science Practice 1.4**]

Learning Objective 3.E.1.3:

The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged.

[See **Science Practice 1.4 and 2.2**]

Learning Objective 3.E.1.4:

The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object.

[See **Science Practice 2.2**]

Enduring Understanding 3.F: A force exerted on an object can cause a torque on that object.

An object or a rigid system, which can revolve or rotate about a fixed axis, will change its rotational motion when an external force exerts a torque on the object. The magnitude of the torque due to a given force is the product of the perpendicular distance from the axis to the line of application of the force (the lever arm) and the magnitude of the force. The rate of change of the rotational motion is most simply expressed by defining the rotational kinematic quantities of angular displacement, angular velocity, and angular acceleration, analogous to the corresponding linear quantities, and defining the rotational dynamic quantities of torque, rotational inertia, and angular momentum, analogous to force, mass, and momentum. The behaviors of the angular displacement, angular velocity, and angular acceleration can be understood by analogy with Newton's second law for linear motion.



Boundary Statement: Quantities such as angular acceleration, velocity, and momentum are defined as vector quantities, but in this course the determination of “direction” is limited to clockwise and counterclockwise with respect to a given axis of rotation.

Essential Knowledge 3.F.1: Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.

- a. The lever arm is the perpendicular distance from the axis of rotation or revolution to the line of application of the force.
- b. The magnitude of the torque is the product of the magnitude of the lever arm and the magnitude of the force.
- c. The net torque on a balanced system is zero.

Learning Objective 3.F.1.1:

The student is able to use representations of the relationship between force and torque.

[See **Science Practice 1.4**]

Learning Objective 3.F.1.2:

The student is able to compare the torques on an object caused by various forces.

[See **Science Practice 1.4**]

Learning Objective 3.F.1.3:

The student is able to estimate the torque on an object caused by various forces in comparison to other situations.

[See **Science Practice 2.3**]

Learning Objective 3.F.1.4:

The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.

[See **Science Practices 4.1, 4.2, and 5.1**]

Learning Objective 3.F.1.5:

The student is able to calculate torques on a two-dimensional system in static equilibrium by examining a representation or model (such as a diagram or physical construction).

[See **Science Practices 1.4 and 2.2**]

Essential Knowledge 3.F.2: The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis.

- Rotational motion can be described in terms of angular displacement, angular velocity, and angular acceleration about a fixed axis.
- Rotational motion of a point can be related to linear motion of the point using the distance of the point from the axis of rotation.
- The angular acceleration of an object or rigid system can be calculated from the net torque and the rotational inertia of the object or rigid system.

Learning Objective 3.F.2.1:

The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.

[See **Science Practice 6.4**]

Learning Objective 3.F.2.2:

The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.

[See **Science Practices 4.1, 4.2, and 5.1**]

Essential Knowledge 3.F.3: A torque exerted on an object can change the angular momentum of an object.

- Angular momentum is a vector quantity, with its direction determined by a right-hand rule.
- The magnitude of angular momentum of a point object about an axis can be calculated by multiplying the perpendicular distance from the axis of rotation to the line of motion by the magnitude of linear momentum.
- The magnitude of angular momentum of an extended object can also be found by multiplying the rotational inertia by the angular velocity.
- The change in angular momentum of an object is given by the product of the average torque and the time the torque is exerted.

Learning Objective 3.F.3.1:

The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 3.F.3.2:

In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.

[See **Science Practice 2.1**]

Learning Objective 3.F.3.3:

The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.

[See **Science Practices 4.1, 4.2, 5.1, and 5.3**]

Enduring Understanding 3.G: Certain types of forces are considered fundamental.

There are different types of fundamental forces, and these forces can be characterized by their actions at different scales. The fundamental forces discussed in these courses include the electroweak force, the gravitational force, and the strong (nuclear) force. The electroweak force unifies the

electromagnetic force and the weak force. These two aspects of the electroweak force dominate at different scales, so are discussed separately. All other forces can be thought of as secondary forces and are ultimately derived from the fundamental forces.

On the scale appropriate to the secondary forces we deal with every day, the electromagnetic aspect of the electroweak force dominates. There are two kinds of electric charge that can produce both attractive and repulsive interactions. While there are two kinds of electric charge, there appears to be only a single type of mass. Consequently, gravitational forces are only attractive. Since there are no repulsive contributions to the net force exerted at a very large distance, the gravitational force dominates at large scales. The weak aspect of the electroweak force is important at very large stellar scales and at very small nuclear scales, and the strong force dominates inside the nucleus. (Students will not be required to know interactions involving the weak force.)

PHYSICS 1	Essential Knowledge 3.G.1: Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.	PHYSICS 2
	Learning Objective 3.G.1.1: The student is able to articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored. [See Science Practice 7.1]	
	Learning Objective 3.G.1.2 : The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces. [See Science Practice 7.1]	PHYSICS 2
	Essential Knowledge 3.G.2: Electromagnetic forces are exerted at all scales and can dominate at the human scale.	PHYSICS 2
	Learning Objective 3.G.2.1: The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved. [See Science Practice 7.1]	

Essential Knowledge 3.G.3: The strong force is exerted at nuclear scales and dominates the interactions of nucleons.

Learning Objective 3.G.3.1:

The student is able to identify the strong force as the force that is responsible for holding the nucleus together.
[See **Science Practice 7.2**]

Big Idea 4: Interactions between systems can result in changes in those systems.

A system is a collection of objects, and the interactions of such systems are an important aspect of understanding the physical world. The concepts and applications in Big Idea 3, which concerned only objects, can be extended to discussions of such systems. The behavior of a system of objects may require a specification of their distribution, which can be described using the center of mass. The motion of the system is then described by Newton's second law as applied to the center of mass. When external forces or torques are exerted on a system, changes in linear momentum, angular momentum, and/or kinetic, potential, or internal energy of the system can occur. Energy transfers, particularly, are at the heart of almost every process that is investigated in the AP sciences. The behavior of electrically charged and magnetic systems can be changed through electromagnetic interactions with other systems.

Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma \vec{F}}{m}$.

The concept of center of mass allows one to analyze and predict the motion of a system using an approach very similar to the way one can analyze and predict the motion of an object. When dealing with a system of objects, it is useful to first identify the forces that are “internal” and “external” to the system. The internal forces are forces that are exerted between objects in the system, while the external forces are those that are exerted between the system's objects and objects outside the system. Internal forces do not affect the motion of the center of mass of the system. Since all the internal forces will be action-reaction pairs, they cancel one another. Thus, $\vec{F}_{\text{net}}$ will be equivalent to the sum of all the external forces, so the acceleration of the center of mass of the system can be calculated using $\vec{a} = \frac{\Sigma \vec{F}}{m}$. Hence, many of the results for the motion of an object can be applied to the motion of the center of mass of a system.



Boundary Statement: Physics 1 includes no calculations of centers of mass; the equation is not provided until Physics 2. However, without doing calculations, Physics 1 students are expected to be able to locate the center of mass of highly symmetric mass distributions, such as a uniform rod or cube of uniform density, or two spheres of equal mass.

PHYSICS 1

Essential Knowledge 4.A.1: The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.

Learning Objective 4.A.1.1:

The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semiquantitatively.

[See **Science Practices 1.2, 1.4, 2.3, and 6.4**]

PHYSICS 1

Essential Knowledge 4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.

- a. The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
- b. Force and acceleration are both vectors, with acceleration in the same direction as the net force.

Learning Objective 4.A.2.1:

The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.

[See **Science Practice 6.4**]

Learning Objective 4.A.2.2

The student is able to evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified.

[See **Science Practice 5.3**]

Learning Objective 4.A.2.3

The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.

[See **Science Practices 1.4 and 2.2**]

PHYSICS 1

Essential Knowledge 4.A.3: Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.

Learning Objective 4.A.3.1:

The student is able to apply Newton's second law to systems to calculate the change in the center-of-mass velocity when an external force is exerted on the system.

[See **Science Practice 2.2**]

Learning Objective 4.A.3.2

The student is able to use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system.

[See **Science Practice 1.4**]

Enduring Understanding 4.B: Interactions with other objects or systems can change the total linear momentum of a system.

When a net external force is exerted on a system, linear momentum is transferred to parts of the system in the direction of the external force. Qualitative comparisons of the change in momentum in different scenarios are important. The change in momentum for a constant-mass system is the product of the mass and the change in velocity. The momentum transferred in an interaction is the product of the average net force and the time interval during which the force is exerted, whether or not the mass is constant. Graphs of force versus time can therefore be used to determine the change in momentum.

PHYSICS 1

Essential Knowledge 4.B.1: The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.

Learning Objective 4.B.1.1:

The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).

[See **Science Practices 1.4 and 2.2**]

Learning Objective 4.B.1.2:

The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.

[See **Science Practice 5.1**]

Essential Knowledge 4.B.2: The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.

- The units for momentum are the same as the units of the area under the curve of a force versus time graph.
- The changes in linear momentum and force are both vectors in the same direction.

Learning Objective 4.B.2.1:

The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.

[See **Science Practice 2.2**]

Learning Objective 4.B.2.2:

The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system.

[See **Science Practice 5.1**]

Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.

A system of objects can be characterized by its total energy, a scalar that is the sum of the kinetic energy (due to large-scale relative motion of parts of the system), its potential energy (due to the relative position of interacting parts of the system), and its microscopic internal energy (due to relative motion and interactions at the molecular and atomic levels of the parts of the system). A single object does not possess potential energy. Rather, the system of which the object is a part has potential energy due to the interactions and relative positions of its constituent objects. In general, kinetic, potential, and internal energies can be changed by interactions with other objects or other systems that transfer energy into or out of the system under study. An external force exerted on an object parallel to the displacement of the object transfers energy into or out of the system. For a force that is constant in magnitude and direction, the product of the magnitude of the parallel force component and the magnitude of the displacement is called the work. For a constant or variable force, the work can be calculated by finding the area under the force versus displacement graph. The force component parallel to the displacement gives the rate of transfer of energy with respect to displacement. Work can result in a change in kinetic energy, potential energy, or internal energy of a system. Positive work transfers energy into the system, while negative work transfers energy out of the system.

There are two mechanisms by which energy transfers into (or out of) a system. One is when the environment does work on the system (defined as positive work on the system), or the system does work on its environment (defined as negative work on the system). The other is when energy is exchanged between two systems at different temperatures, with no work involved. The amount of energy transferred through work done on or by a system is called work and the amount of energy transferred by heating a system is called heat. Work and heat are not "kinds" of energy (like potential or kinetic), rather they are the specific amount of energy transferred by each process. Summing work and heat gives the change in a system's energy.

Classically, mass conservation and energy conservation are separate laws; but in modern physics we recognize that the mass of a system changes when its energy changes so that a transfer of energy into a system entails an increase in the mass of that system as well, although in most processes the change in mass is small enough to be ignored. The relationship between the mass and energy of a system is described by Einstein's famous equation, $E = mc^2$. The large energies produced during nuclear fission and fusion processes correspond to small reductions in the mass of a system.



Boundary Statement: Thermodynamics is treated in Physics 2 only.

PHYSICS 1

Essential Knowledge 4.C.1: The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.

Learning Objective 4.C.1.1:

The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.

[See **Science Practices 1.4, 2.1, and 2.2**]

Learning Objective 4.C.1.2:

The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.

[See **Science Practice 6.4**]

Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.

- a. If the force is constant during a given displacement, then the work done is the product of the displacement and the component of the force parallel or antiparallel to the displacement.
- b. Work (change in energy) can be found from the area under a graph of the magnitude of the force component parallel to the displacement versus displacement.

Learning Objective 4.C.2.1:

The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.

[See **Science Practice 6.4**]

Learning Objective 4.C.2.2:

The student is able to apply the concepts of conservation of energy and the work-energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.

[See **Science Practices 1.4, 2.2, and 7.2**]

Essential Knowledge 4.C.3: Energy is transferred spontaneously from a higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat.

- a. Conduction, convection, and radiation are mechanisms for this energy transfer.
- b. At a microscopic scale the mechanism of conduction is the transfer of kinetic energy between particles.
- c. During average collisions between molecules, kinetic energy is transferred from faster molecules to slower molecules.

Learning Objective 4.C.3.1:

The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level.

[See **Science Practice 6.4**]

Essential Knowledge 4.C.4: Mass can be converted into energy, and energy can be converted into mass.

- a. Mass and energy are interrelated by $E = mc^2$.
- b. Significant amounts of energy can be released in nuclear processes.

Learning Objective 4.C.4.1:

The student is able to apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.

[See **Science Practices 2.2, 2.3, and 7.2**]

Enduring Understanding 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.

Systems not only translate, they can also rotate. The behavior of such a system of objects requires a specification of their distribution in terms of a rotational inertia and an analysis relative to an appropriate axis. The existence of a net torque with respect to an axis will cause the object to change its rate of rotation with respect to that axis. Many everyday phenomena involve rotating systems. Understanding the effects of a nonzero net torque on a system in terms of the angular momentum leads to a better understanding of systems that roll

or rotate. The angular momentum is a quantity that is conserved if the net torque on an object is zero, and this leads to one of the conservation laws discussed in Big Idea 5. Students will be provided with the value for rotational inertia or formula to calculate rotational inertia where necessary.

PHYSICS 1

Essential Knowledge 4.D.1: Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis.

Learning Objective 4.D.1.1:

The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system.

[See **Science Practices 1.2 and 1.4**]

Learning Objective 4.D.1.2:

The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.

[See **Science Practices 3.2, 4.1, 4.2, 5.1, and 5.3**]

PHYSICS 1

Essential Knowledge 4.D.2: The angular momentum of a system may change due to interactions with other objects or systems.

- The angular momentum of a system with respect to an axis of rotation is the sum of the angular momenta, with respect to that axis, of the objects that make up the system.
- The angular momentum of an object about a fixed axis can be found by multiplying the momentum of the particle by the perpendicular distance from the axis to the line of motion of the object.
- Alternatively, the angular momentum of a system can be found from the product of the system's rotational inertia and its angular velocity.

Learning Objective 4.D.2.1:

The student is able to describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems.

[See **Science Practices 1.2 and 1.4**]

Learning Objective 4.D.2.2

The student is able to plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems.

[See **Science Practice 4.2**]

PHYSICS 1

Essential Knowledge 4.D.3: The change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted.

Learning Objective 4.D.3.1:

The student is able to use appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum.

[See **Science Practice 2.2**]

Learning Objective 4.D.3.2:

The student is able to plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted.

[See **Science Practices 4.1 and 4.2**]

Enduring Understanding 4.E: The electric and magnetic properties of a system can change in response to the presence of, or changes in, other objects or systems.

Electric and magnetic forces may be exerted on objects that possess an electric charge. These forces affect the motion of electrically charged objects. If a charged object is part of a system, electric and magnetic forces and fields can affect the properties of the system. One such example involves the behavior of moving charged objects (i.e., an electric current) in a circuit. The electric current in a circuit can be affected by an applied potential difference or by changing the magnetic flux through the circuit. The behavior of individual circuit elements, such as resistors and capacitors, can be understood in terms of how an applied electric or magnetic field affects charge motion within the circuit element.

Essential Knowledge 4.E.1: The magnetic properties of some materials can be affected by magnetic fields at the system. Students should focus on the underlying concepts and not the use of the vocabulary.

- a. Ferromagnetic materials can be permanently magnetized by an external field that causes the alignment of magnetic domains or atomic magnetic dipoles.
- b. Paramagnetic materials interact weakly with an external magnetic field in that the magnetic dipole moments of the material do not remain aligned after the external field is removed.
- c. All materials have the property of diamagnetism in that their electronic structure creates a (usually) weak alignment of the dipole moments of the material opposite to the external magnetic field.

Learning Objective 4.E.1.1:

The student is able to use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by magnetic properties of other objects in the system.

[See **Science Practices 1.1, 1.4, and 2.2**]

Essential Knowledge 4.E.2: Changing magnet flux induces an electric field that can establish an induced emf in a system.

- a. Changing magnetic flux induces an emf in a system, with the magnitude of the induced emf equal to the rate of change in magnetic flux.
- b. When the area of the surface being considered is constant, the induced emf is the area multiplied by the rate of change in the component of the magnetic field perpendicular to the surface.
- c. When the magnetic field is constant, the induced emf is the magnetic field multiplied by the rate of change in area perpendicular to the magnetic field.
- d. The conservation of energy determines the direction of the induced emf relative to the change in the magnetic flux.

Learning Objective 4.E.2.1:

The student is able to construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area.

[See **Science Practice 6.4**]

Essential Knowledge 4.E.3: The charge distribution in a system can be altered by the effects of electric forces produced by a charged object.

- a. Charging can take place by friction or by contact.
- b. An induced charge separation can cause a neutral object to become polarized.
- c. Charging by induction can occur when a polarizing conducting object is touched by another.
- d. In solid conductors, some electrons are mobile. When no current flows, mobile charges are in static equilibrium, excess charge resides at the surface, and the interior field is zero. In solid insulators, excess (fixed) charge may reside in the interior as well as at the surface.

Learning Objective 4.E.3.1:

The student is able to make predictions about the redistribution of charge during charging by friction, conduction, and induction.
[See **Science Practice 6.4**]

Learning Objective 4.E.3.2:

The student is able to make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects.
[See **Science Practices 6.4 and 7.2**]

Learning Objective 4.E.3.3:

The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors.
[See **Science Practices 1.1, 1.4, and 6.4**]

Learning Objective 4.E.3.4:

The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction.
[See **Science Practices 1.1, 1.4, and 6.4**]

Learning Objective 4.E.3.5:

The student is able to explain and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure.
[See **Science Practices 3.2, 4.1, 4.2, 5.1, and 5.3**]

Essential Knowledge 4.E.4: The resistance of a resistor and the capacitance of a capacitor can be understood from the basic properties of electric fields and forces as well as the properties of materials and their geometry.

- a. The resistance of a resistor is proportional to its length and inversely proportional to its cross-sectional area. The constant of proportionality is the resistivity of the material.
- b. The capacitance of a parallel plate capacitor is proportional to the area of one of its plates and inversely proportional to the separation between its plates. The constant of proportionality is the product of the dielectric constant, κ , of the material between the plates and the electric permittivity, ϵ_0 .
- c. The current through a resistor is equal to the potential difference across the resistor divided by its resistance.
- d. The magnitude of charge of one of the plates of a parallel plate capacitor is directly proportional to the product of the potential difference across the capacitor and the capacitance. The plates have equal amounts of charge of opposite sign.

Learning Objective 4.E.4.1:

The student is able to make predictions about the properties of resistors and/or capacitors when placed in a simple circuit based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.

[See **Science Practices 2.2 and 6.4**]

Learning Objective 4.E.4.2:

The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

[See **Science Practices 4.1 and 4.2**]

Learning Objective 4.E.4.3:

The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

[See **Science Practice 5.1**]

Essential Knowledge 4.E.5: The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.

Learning Objective 4.E.5.1:

The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

[See **Science Practices 2.2 and 6.4**]

Learning Objective 4.E.5.2:

The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

[See **Science Practices 6.1 and 6.4**]

Learning Objective 4.E.5.3:

The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.

[See **Science Practices 2.2, 4.2, and 5.1**]

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Conservation laws constrain the possible behaviors of the objects in a system of any size or the outcome of an interaction or a process. Associated with every conservation law is a physical quantity, a scalar or a vector, which characterizes a system. In a closed and isolated system, that quantity has a constant value, independent of interactions between objects in the system for all configurations of the system. In an open system, the changes of that quantity are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. Thus, conservation laws constrain the possible configurations of a system. Among many conservation laws, several apply across all scales. Conservation of energy is pervasive across all areas of physics and across all the sciences. All processes in nature conserve the net electric charge. Whether interactions are elastic or inelastic, linear momentum and angular momentum

are conserved. When analyzing a physical situation, the choice of a system and the expression of the conservation laws provide a quick and powerful set of tools to express mathematical constraints relating the variables in the system.

Enduring Understanding 5.A: Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.

Conservation laws constrain the possible motions of the objects in a system of any size, or the outcome of an interaction or a process. For example, thinking about physical systems from the perspective of Newton's second law, each object changes its motion at any instant in response to external forces and torques, its response constrained only by its inertial mass and the distribution of that mass. However, with even a few objects in a system, tracking the motions becomes very complex. Associated with every conservation law is a physical quantity, a scalar or a vector, which characterizes a system. In a closed and isolated system, that quantity has a constant value, independent of interactions between objects in the system for all configurations of the system. In an open system, the changes of that quantity are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems. Thus, the conservation law constrains the possible configurations of a system. When analyzing a physical situation, the choice of a system and the expression of the conservation laws provide a quick and powerful set of tools to express mathematical constraints relating the variables in the system.

PHYSICS 1

Essential Knowledge 5.A.1: A system is an object or a collection of objects. The objects are treated as having no internal structure.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 1

Essential Knowledge 5.A.2: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.

Learning Objective 5.A.2.1:

The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.

[See **Science Practices 6.4 and 7.2**]

PHYSICS 1

Essential Knowledge 5.A.3: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

PHYSICS 1

Essential Knowledge 5.A.4: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.

Content Connection:

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

Enduring Understanding 5.B: The energy of a system is conserved.

Of all the conservation laws, the conservation of energy is the most pervasive across all areas of physics and across all the sciences. Conservation of energy occurs in all physical, chemical, biological, and environmental processes, and these isolated ideas are connected by this enduring understanding. Several of the concepts included under this enduring understanding are statements about the conservation of energy: Kirchhoff's loop rule for electric circuits, Bernoulli's equation for fluids, and the change in internal energy of a thermodynamic system due to heat or work. In nuclear processes, interconversion of energy and mass occurs, and the conservation principle is extended.

Energy is conserved in any system, whether that system is physical, biological, or chemical. An object can have kinetic energy; systems can have kinetic energy; but, if they have internal structure, changes in that internal structure can result in changes in internal energy and potential energy. If a closed system's potential energy or internal energy changes, that energy change can result in changes to the system's kinetic energy. In systems that are open to energy transfer, changes in the total energy can be due to external forces (work is done), thermal contact processes (heating occurs), or to emission or absorption of photons (radiative processes). Energy transferred into or out of a system can change kinetic, potential, and internal energies of the system. These exchanges provide information about properties of the system. If photons are emitted or absorbed, then there is a change in the energy states for atoms in the system.



Boundary Statement: Conservation principles apply in the context of the appropriate Physics 1 and Physics 2 courses. Work, potential energy, and kinetic energy concepts are related to mechanical systems in Physics 1 and electric, magnetic, thermal, and atomic and elementary particle systems in Physics 2.

PHYSICS 1

Essential Knowledge 5.B.1: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.

Learning Objective 5.B.1.1:

The student is able to set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.

[See **Science Practices 1.4 and 2.2**]

Learning Objective 5.B.1.2:

The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.

[See **Science Practice 1.5**]

PHYSICS 1

Essential Knowledge 5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [Physics 1: includes mass-spring oscillators and simple pendulums. Physics 2: includes charged object in electric fields and examining changes in internal energy with changes in configuration.]

PHYSICS 2

Learning Objective 5.B.2.1:

The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.

[See **Science Practices 1.4 and 2.1**]

Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.

- The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.
- Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators and objects falling in a gravitational field.
- The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.]

Learning Objective 5.B.3.1:

The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

[See **Science Practices 2.2, 6.4, and 7.2**]

Learning Objective 5.B.3.2:

The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

[See **Science Practices 1.4 and 2.2**]

Learning Objective 5.B.3.3:

The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

[See **Science Practices 1.4 and 2.2**]

PHYSICS 1

Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.

- Since energy is constant in a closed system, changes in a system's potential energy can result in changes to the system's kinetic energy.
- The changes in potential and kinetic energies in a system may be further constrained by the construction of the system.

Learning Objective 5.B.4.1:

The student is able to describe and make predictions about the internal energy of systems.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.B.4.2:

The student is able to calculate changes in kinetic energy and potential energy of a system using information from representations of that system.

[See **Science Practices 1.4, 2.1, and 2.2**]

PHYSICS 2

PHYSICS 1

Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. [A piston filled with gas getting compressed or expanded is treated in Physics 2 as a part of thermodynamics.]

Learning Objective 5.B.5.1:

The student is able to design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.

[See **Science Practices 4.2 and 5.1**]

PHYSICS 2

Learning Objective 5.B.5.2:

The student is able to design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.

[See **Science Practices 4.2 and 5.1**]

Learning Objective 5.B.5.3:

The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through distance.

[See **Science Practices 1.4, 2.2, and 6.4**]

Learning Objective 5.B.5.4:

The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).

[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.B.5.5:

The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

[See **Science Practices 2.2 and 6.4**]

Learning Objective 5.B.5.6:

The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system.

[See **Science Practices 4.2 and 5.1**]

Essential Knowledge 5.B.6: Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.

Learning Objective 5.B.6.1:

The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.

[See **Science Practice 1.2**]

Essential Knowledge 5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.

Learning Objective 5.B.7.1:

The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.B.7.2:

The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.

[See **Science Practice 1.1**]

Learning Objective 5.B.7.3:

The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics).

[See **Science Practices 1.1, 1.4, and 2.2**]

Essential Knowledge 5.B.8: Energy transfer occurs when photons are absorbed or emitted, for example, by atoms or nuclei.

- Transitions between two given energy states of an atom correspond to the absorption or emission of a photon of a given frequency (and hence, a given wavelength).
- An emission spectrum can be used to determine the elements in a source of light.

Learning Objective 5.B.8.1:

The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.

[See **Science Practices 1.2 and 7.2**]

Essential Knowledge 5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]

- Energy changes in simple electrical circuits are conveniently represented in terms of energy change per charge moving through a battery and a resistor.
- Since electric potential difference times charge is energy, and energy is conserved, the sum of the potential differences about any closed loop must add to zero.
- The electric potential difference across a resistor is given by the product of the current and the resistance.
- The rate at which energy is transferred from a resistor is equal to the product of the electric potential difference across the resistor and the current through the resistor.
- Energy conservation can be applied to combinations of resistors and capacitors in series and parallel circuits.

Learning Objective 5.B.9.1:

The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule). [See **Science Practices 1.1 and 1.4**]

Learning Objective 5.B.9.2:

The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ($\sum \Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. [See **Science Practices 4.2, 6.4, and 7.2**]

Learning Objective 5.B.9.3:

The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [See **Science Practices 2.2, 6.4, and 7.2**]

Learning Objective 5.B.9.4: The student is able to analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff’s loop rule ($\sum \Delta V = 0$). [See Science Practice 5.1]	PHYSICS 2
Learning Objective 5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff’s loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. [See Science Practice 6.4]	
Learning Objective 5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. [See Science Practices 2.1 and 2.2]	
Learning Objective 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff’s loop rule for circuits that includes determination of internal resistance of the battery and analysis of a nonohmic resistor. [See Science Practices 4.1, 4.2, 5.1, and 5.3]	
Learning Objective 5.B.9.8: The student is able to translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor. [See Science Practice 1.5]	
Essential Knowledge 5.B.10: Bernoulli’s equation describes the conservation of energy in fluid flow.	PHYSICS 2
Learning Objective 5.B.10.1: The student is able to use Bernoulli’s equation to make calculations related to a moving fluid. [See Science Practice 2.2]	
Learning Objective 5.B.10.2: The student is able to use Bernoulli’s equation and/or the relationship between force and pressure to make calculations related to a moving fluid. [See Science Practice 2.2]	

Learning Objective 5.B.10.3:

The student is able to use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid.

[See **Science Practice 2.2**]

Learning Objective 5.B.10.4:

The student is able to construct an explanation of Bernoulli's equation in terms of the conservation of energy.

[See **Science Practice 6.2**]

Essential Knowledge 5.B.11: Beyond the classical approximation, mass is actually part of the internal energy of an object or system with $E = mc^2$.

- a. $E = mc^2$ can be used to calculate the mass equivalent for a given amount of energy transfer or an energy equivalent for a given amount of mass change (e.g., fission and fusion reactions).

Learning Objective 5.B.11.1:

The student is able to apply conservation of mass and conservation of energy concepts to a natural phenomenon and use the equation $E = mc^2$ to make a related calculation.

[See **Science Practices 2.2 and 7.2**]

Enduring Understanding 5.C: The electric charge of a system is conserved.

Conservation of electric charge is a fundamental conservation principle in physics. All processes in nature conserve the net electric charge. The total electric charge after an interaction or any other type of process always equals the total charge before the interaction or process. A common example is found in electric circuits, in which charge (typically electrons) moves around a circuit or from place to place within a circuit. Any increase or decrease in the net charge in one region is compensated for by a corresponding decrease or increase in the net charge in other regions. In electrostatics, it is common for electrons to move from one object to another, and the number of electrons that leave one object is always equal to the number of electrons that move onto other objects. In some reactions such as radioactive decay or interactions involving elementary particles, it is possible for the number of electrically charged particles after a reaction or decay to be different from the number before. However, the net charge before and after is always equal. So, if a process produces a “new” electron that was not present before the reaction, then a “new” positive charge must also be created so that the net charge is the same before and after the process.

Essential Knowledge 5.C.1: Electric charge is conserved in nuclear and elementary particle reactions, even when elementary particles are produced or destroyed. Examples should include equations representing nuclear decay.

Learning Objective 5.C.1.1:

The student is able to analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge.

[See **Science Practices 6.4 and 7.2**]

Essential Knowledge 5.C.2: The exchange of electric charges among a set of objects in a system conserves electric charge.

- a. Charging by conduction between objects in a system conserves the electric charge of the entire system.
- b. Charge separation in a neutral system can be induced by an external charged object placed close to the neutral system.
- c. Grounding involves the transfer of excess charge to another larger system (e.g., the Earth).

Learning Objective 5.C.2.1:

The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system.

[See **Science Practice 6.4**]

Learning Objective 5.C.2.2:

The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data.

[See **Science Practices 4.2 and 5.1**]

Learning Objective 5.C.2.3:

The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects.

[See **Science Practice 4.1**]

PHYSICS 1	Essential Knowledge 5.C.3: Kirchhoff’s junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Physics 1: covers circuits with resistors in series, with at most one parallel branch, one battery only. Physics 2: includes capacitors in steady-state situations. For circuits with capacitors, situations should be limited to open circuit, just after circuit is closed, and a long time after the circuit is closed.]	PHYSICS 2
PHYSICS 1	Learning Objective 5.C.3.1: The student is able to apply conservation of electric charge (Kirchhoff’s junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. [See Science Practices 6.4 and 7.2] Learning Objective 5.C.3.2: The student is able to design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. [See Science Practices 4.1, 4.2, and 5.1] Learning Objective 5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [See Science Practices 1.4 and 2.2]	
	Learning Objective 5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff’s junction rule and relate the rule to the law of charge conservation. [See Science Practices 6.4 and 7.2] Learning Objective 5.C.3.5: The student is able to determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. [See Science Practices 1.4 and 2.2]	PHYSICS 2

Learning Objective 5.C.3.6:

The student is able to determine missing values and direction of electric current in branches of a circuit with both resistors and capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.

[See **Science Practices 1.4 and 2.2**]

Learning Objective 5.C.3.7:

The student is able to determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit.

[See **Science Practices 1.4 and 2.2**]

Enduring Understanding 5.D: The linear momentum of a system is conserved.

Conservation of linear momentum is another of the important conservation laws. This law holds at all scales from the subatomic scale to the galactic scale. Linear momentum in a system isolated from external forces is constant. Interactions with other objects or systems can change the total linear momentum of a system. Such changes are discussed in Enduring Understandings 3.D and 4.B.

When objects collide, the collisions can be elastic or inelastic. In both types of collisions linear momentum is conserved. The elastic collision of nonrotating objects describes those cases in which the linear momentum stays constant and the kinetic and internal energies of the system are the same before and after the collision. The inelastic collision of objects describes those cases in which the linear momentum stays constant and the kinetic and internal energies of the objects are different before and after the collision.

The velocity of the center of mass of the system cannot be changed by an interaction within the system. In an isolated system that is initially stationary, the location of the center of mass is fixed. When two objects collide, the velocity of their center of mass will not change.



Boundary Statement: Physics 1 includes a quantitative and qualitative treatment of conservation of momentum in one dimension and a semiquantitative treatment of conservation of momentum in two dimensions. Items involving solution of simultaneous equations are not included in either Physics 1 or Physics 2, but items testing whether students can set up the equations properly and can reason about how changing a given

mass, speed, or angle would affect other quantities are included. Physics 1 includes only conceptual understanding of center of mass motion of a system without the need for calculation of center of mass. Physics 2 includes full qualitative and quantitative two-dimensional treatment of conservation of momentum and velocity of the center of mass of the system. The Physics 1 course will include topics from this enduring understanding in the context of mechanical systems. The Physics 2 course will include content from this enduring understanding that involves interactions arising in the context of topics such as nuclear decay, other nuclear reactions, and interactions of subatomic particles with each other and with photons.

PHYSICS 1	Essential Knowledge 5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after. a. In an isolated system, the linear momentum is constant throughout the collision. b. In an isolated system, the kinetic energy after an elastic collision is the same as the kinetic energy before the collision.	PHYSICS 2
	Learning Objective 5.D.1.1: The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. [See Science Practices 6.4 and 7.2]	
	Learning Objective 5.D.1.2: The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations. [See Science Practices 2.2, 3.2, 5.1, and 5.3]	

Learning Objective 5.D.1.3:

The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.

[See **Science Practices 2.1 and 2.2**]

Learning Objective 5.D.1.4:

The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.

[See **Science Practices 4.2, 5.1, 5.3, and 6.4**]

Learning Objective 5.D.1.5:

The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

[See **Science Practices 2.1 and 2.2**]

Learning Objective 5.D.1.6:

The student is able to make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed.

[See **Science Practice 6.4**]

Learning Objective 5.D.1.7:

The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

[See **Science Practices 2.1 and 2.2**]

Essential Knowledge 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.

- In an isolated system, the linear momentum is constant throughout the collision.
- In an isolated system, the kinetic energy after an inelastic collision is different from the kinetic energy before the collision.

Learning Objective 5.D.2.1:

The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.
[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.D.2.2:

The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
[See **Science Practices 4.1, 4.2, and 5.1**]

Learning Objective 5.D.2.3:

The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.D.2.4:

The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force.
[See **Science Practices 4.1, 4.2, 4.4, 5.1, and 5.3**]

Learning Objective 5.D.2.5:

The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.
[See **Science Practices 2.1 and 2.2**]

Learning Objective 5.D.2.6:

The student is able to apply the conservation of linear momentum to an isolated system of objects involved in an inelastic collision to predict the change in kinetic energy.
[See **Science Practices 6.4 and 7.2**]

Essential Knowledge 5.D.3: The velocity of the center of mass of the system cannot be changed by an interaction within the system. [Physics 1: includes no calculations of centers of mass; the equation is not provided until Physics 2. However, without doing calculations, Physics 1 students are expected to be able to locate the center of mass of highly symmetric mass distributions, such as a uniform rod or cube of uniform density, or two spheres of equal mass.]

- a. The center of mass of a system depends upon the masses and positions of the objects in the system. In an isolated system (a system with no external forces), the velocity of the center of mass does not change.
- b. When objects in a system collide, the velocity of the center of mass of the system will not change unless an external force is exerted on the system.

Learning Objective 5.D.3.1:

The student is able to predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force).

[See **Science Practice 6.4**]

Learning Objective 5.D.3.2:

The student is able to make predictions about the velocity of the center of mass for interactions within a defined one-dimensional system.

[See **Science Practice 6.4**]

Learning Objective 5.D.3.3:

The student is able to make predictions about the velocity of the center of mass for interactions within a defined two-dimensional system.

[See **Science Practice 6.4**]

Enduring Understanding 5.E: The angular momentum of a system is conserved.

The conservation of angular momentum is a consequence of the symmetry of physical laws under rotation, which means that if everything relevant to an experiment is turned through some angle, the results of the experiment will be the same. In nature, conservation of angular momentum helps to explain the vortex of the bathtub drain; the rotation of ocean currents; the changing spin of a dancer, a skater, a gymnast, and a diver; the direction of rotation of cyclonic weather systems; and the roughly planar arrangement of planetary systems and galaxies. The angular momentum of a rigid system of objects allows us to describe the linked trajectories of the many objects in the system with a single number, which is unchanging when no external torques are applied. Choosing such an isolated system for analyzing a rotational situation allows many problems to be solved by equating the total angular momentum in two configurations of the system. Students will be provided with the value for rotational inertia or formula to calculate rotational inertia where necessary.

PHYSICS 1

Essential Knowledge 5.E.1: If the net external torque exerted on the system is zero, the angular momentum of the system does not change.

Learning Objective 5.E.1.1:

The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 5.E.1.2:

The student is able to make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero.

[See **Science Practices 2.1 and 2.2**]

Essential Knowledge 5.E.2: The angular momentum of a system is determined by the locations and velocities of the objects that make up the system. The rotational inertia of an object or system depends upon the distribution of mass within the object or system. Changes in the radius of a system or in the distribution of mass within the system result in changes in the system's rotational inertia, and hence in its angular velocity and linear speed for a given angular momentum. Examples should include elliptical orbits in an Earth-satellite system. Mathematical expressions for the moments of inertia will be provided where needed. Students will not be expected to know the parallel axis theorem.

Learning Objective 5.E.2.1:

The student is able to describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses. [See **Science Practice 2.2**]

Enduring Understanding 5.F: Classically, the mass of a system is conserved.

The conservation of mass is an important principle that holds up to a certain energy scale where the concepts of mass and energy need to be combined. In this course, conservation of mass is assumed in most problems. Thus, when using $\vec{a} = \frac{\Sigma \vec{F}}{m}$, etc., conservation of mass is assumed.

An ideal example of this conservation law is found in the continuity equation, which describes conservation of mass flow rate in fluids. If no mass is entering or leaving a system, then the mass must be constant. If an enclosed fluid flow is uniform and the fluid is also incompressible, then the mass entering an area must be equal to the mass leaving an area. Fluid flow in engineering and in biological systems can be modeled starting with this enduring understanding but requires the addition of fluid viscosity for a complete treatment, which is not a part of this course.

Essential Knowledge 5.F.1: The continuity equation describes conservation of mass flow rate in fluids. Examples should include volume rate of flow and mass flow rate.

Learning Objective 5.F.1.1:

The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation).
[See **Science Practices 2.1, 2.2, and 7.2**]

Enduring Understanding 5.G: Nucleon number is conserved.

The conservation of nucleon number, according to which the number of nucleons (protons and neutrons) doesn't change, applies to nuclear reactions and decays including fission, fusion, alpha decay, beta decay, and gamma decay. This conservation law, along with conservation of electric charge, is the basis for balancing nuclear equations.

Essential Knowledge 5.G.1: The possible nuclear reactions are constrained by the law of conservation of nucleon number.

Learning Objective 5.G.1.1:

The student is able to apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.
[See **Science Practice 6.4**]

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Classically, waves are a “disturbance” that propagates through space. Mechanical waves are a disturbance of a mechanical medium such as a string, a solid, or a gas, and they carry energy and momentum from one place to another without any net motion of the medium. Electromagnetic waves are a different type of wave; in this case, the disturbance is in the electromagnetic

field itself, and therefore requires no medium. Electromagnetic waves also carry energy and momentum. In most cases, multiple waves can propagate through a medium independently of each other. Two waves do not “collide” as would objects traveling through the same region of space. Waves “pass through” each other, according to the principle of superposition and a phenomenon called interference. Important examples of wave motion are sound (a mechanical wave that can propagate in gases, liquids, and solids), and light (which can be modeled as electromagnetic waves to which our eyes are sensitive). In the quantum regime, all particles can be modeled as waves, although the wavelike behavior is only observable under certain conditions — for example, an electron in an atom behaves in some ways like a classical particle and in other ways like a classical wave.



Boundary Statement: Physics 1 will treat mechanical waves only. Mathematical modeling of waves using sines or cosines is included in Physics 2. Superposition of no more than two wave pulses and properties of standing waves is evaluated in Physics 1. Interference is revisited in Physics 2, where two-source interference and diffraction may be demonstrated with mechanical waves, leading to the development of these concepts in the context of electromagnetic waves, the focus of Physics 2.

Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.

When an object moves as a projectile from one place to another, it possesses kinetic energy and momentum. Such a process thus transfers energy and momentum, and also mass, from place to place. A wave is a disturbance that carries energy and momentum from one place to another without the transfer of mass. Some waves are mechanical in nature — this means that they are a disturbance of a mechanical system such as a solid, a liquid, or a gas; this system is called the medium through which the wave travels. Mechanical waves are then described in terms of the way they disturb or displace their medium. The propagation properties of the mechanical wave, such as the wave speed, also depend on the properties of the medium. Electromagnetic waves do not require a mechanical medium. They are instead associated with oscillating electric and magnetic fields. Electromagnetic waves can travel through a mechanical medium, such as a solid, but they can also travel through a vacuum.

PHYSICS 1	Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal. a. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves. b. Electromagnetic waves are transverse waves. c. Transverse waves may be polarized.	PHYSICS 2
PHYSICS 1	Learning Objective 6.A.1.1: The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave. [See Science Practice 6.2]	
	Learning Objective 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [See Science Practice 1.2]	PHYSICS 2
	Learning Objective 6.A.1.3: The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation. [See Science Practices 5.1 and 6.2]	
PHYSICS 1	Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.	PHYSICS 2
	Learning Objective 6.A.2.1: The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. [See Science Practices 6.4 and 7.2]	
	Learning Objective 6.A.2.2: The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation. [See Science Practices 6.4 and 7.2]	PHYSICS 2

PHYSICS 1

Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.

Learning Objective 6.A.3.1:

The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.
[See **Science Practice 1.4**]

PHYSICS 1

Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.

Learning Objective 6.A.4.1:

The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.
[See **Science Practice 6.4**]

Enduring Understanding 6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.

The properties of periodic waves are important to understanding wave phenomena in the world around us. These properties are amplitude, frequency, period, speed of the wave in a particular medium, wavelength, and energy. A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave. Wave speeds depend upon the properties of the medium, but the speed of a wave is generally independent of the frequency and wavelength of the wave. The speed of an electromagnetic wave in a vacuum is a constant, usually referred to as c . In other materials, the apparent speed of an electromagnetic wave depends on properties of the material.

The frequency of a wave, as perceived by observers, depends upon the relative motion of the source and the observer. If the relative motions of the source and observer are away from each other, the perceived frequency decreases. If the relative motions of the source and observer are toward each other, the perceived frequency increases. This change in observed frequency or wavelength is known as the Doppler effect and finds uses from astronomy to medicine to radar speed traps.

PHYSICS 1

Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.

Learning Objective 6.B.1.1:

The student is able to use a graphical representation of a periodic mechanical wave (position vs. time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.

[See **Science Practices 1.4 and 2.2**]

PHYSICS 1

Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.

Learning Objective 6.B.2.1:

The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.

[See **Science Practice 1.4**]

PHYSICS 2

Essential Knowledge 6.B.3: A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave.

Learning Objective 6.B.3.1:

The student is able to construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa.

[See **Science Practice 1.5**]

PHYSICS 1

Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.

Learning Objective 6.B.4.1:

The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

[See **Science Practices 4.2, 5.1, and 7.2**]

PHYSICS 1

Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

Learning Objective 6.B.5.1:

The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

[See **Science Practice 1.4**]

Enduring Understanding 6.C: Only waves exhibit interference and diffraction.

When two or more waves move through the same space, the displacement at a particular point is a result of the superposition or sum of the displacements due to each of the waves. Depending on the direction of propagation of the waves from the various sources and their phase or time relationship to each other, this principle explains a large variety of phenomena, including standing waves in a musical instrument, rogue waves at sea, and the colors seen in soap bubbles. Where the crest of one wave coincides with the crest of another wave, constructive interference occurs, producing large amplitude oscillations. Where crest meets trough, cancellation or destructive interference occurs. Since the oscillation at a particular point can be treated as a source of waves spreading from that point (Huygens' principle), as waves pass through openings or around objects that are of sizes comparable to the wavelength, we observe that waves can spread or diffract out into the space beyond the edge or obstacle, which accounts, among other things, for our ability to hear around corners, but not see around them.

Essential Knowledge 6.C.1: When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.

Learning Objective 6.C.1.1:

The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves.

[See **Science Practices 6.4 and 7.2**]

Learning Objective 6.C.1.2:

The student is able to construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.

[See **Science Practice 1.4**]

PHYSICS 2

Essential Knowledge 6.C.2: When waves pass through an opening whose dimensions are comparable to the wavelength, a diffraction pattern can be observed.

Learning Objective 6.C.2.1:

The student is able to make claims about the diffraction pattern produced when a wave passes through a small opening and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave.

[See **Science Practices 1.4, 6.4, and 7.2**]

Essential Knowledge 6.C.3: When waves pass through a set of openings whose spacing is comparable to the wavelength, an interference pattern can be observed. Examples should include monochromatic double-slit interference.

Learning Objective 6.C.3.1:

The student is able to qualitatively apply the wave model to quantities that describe the generation of interference patterns to make predictions about interference patterns that form when waves pass through a set of openings whose spacing and widths are small, but larger than the wavelength.

[See **Science Practices 1.4 and 6.4**]

Essential Knowledge 6.C.4: When waves pass by an edge, they can diffract into the “shadow region” behind the edge. Examples should include hearing around corners, but not seeing around them, and water waves bending around obstacles.

Learning Objective 6.C.4.1:

The student is able to predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light.

[See **Science Practices 6.4 and 7.2**]

Enduring Understanding 6.D: Interference and superposition lead to standing waves and beats.

Interference and superposition of waves find application in many areas. These include musical instruments, lasers, medical imaging, and the search for gravitational waves. Two wave pulses can overlap to produce amplitude variations in the resultant wave. At the moment of overlap, the displacement at each point can be determined by superposition, adding the displacements at each point due to the individual pulses. This principle applies to all waves from pulses to traveling periodic waves.

When incident and reflected traveling waves are confined to a region, their superposition or addition can result in standing waves with constructive and destructive interference at different points in space. Examples include waves on a fixed length of string and sound waves in a tube. When two waves of slightly different frequency superimpose, their superposition or addition can result in beats with constructive and destructive interference at different points in time. Standing waves and beats are important phenomena in music.

PHYSICS 1

Essential Knowledge 6.D.1: Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.

Learning Objective 6.D.1.1:

The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.

[See **Science Practices 1.1 and 1.4**]

Learning Objective 6.D.1.2:

The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).

[See **Science Practices 4.2 and 5.1**]

Learning Objective 6.D.1.3:

The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.

[See **Science Practice 4.2**]

PHYSICS 1

Essential Knowledge 6.D.2: Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.

Learning Objective 6.D.2.1:

The student is able to analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.

[See **Science Practice 5.1**]

PHYSICS 1

Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string and sound waves in both closed and open tubes.

Learning Objective 6.D.3.1:

The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.

[See **Science Practices 2.1, 3.2, and 4.2**]

Learning Objective 6.D.3.2:

The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.

[See **Science Practice 6.4**]

Learning Objective 6.D.3.3:

The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.

[See **Science Practices 3.2, 4.1, 5.1, 5.2, and 5.3**]

Learning Objective 6.D.3.4:

The **student** is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.

[See **Science Practice 1.2**]

PHYSICS 1

Essential Knowledge 6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.

- A standing wave with zero amplitude at both ends can only have certain wavelengths. Examples should include fundamental frequencies and harmonics.
- Other boundary conditions or other region sizes will result in different sets of possible wavelengths.

Learning Objective 6.D.4.1:

The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.

[See **Science Practices 1.5 and 6.1**]

Learning Objective 6.D.4.2

The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

[See **Science Practice 2.2**]

PHYSICS 1

Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency.

- Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument.
- The beat frequency is the difference in frequency between the two waves.

Learning Objective 6.D.5.1:

The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

[See **Science Practice 1.2**]

Enduring Understanding 6.E: The direction of propagation of a wave such as light may be changed when the wave encounters an interface between two media.

The propagation of a wave depends on the properties of the medium or region through which the wave travels. The speed of a wave, including electromagnetic waves such as light, depends on the material through which it travels. When light (or any other type of wave) travels from one material to another, the frequency remains the same, but the change in wave speed causes a change in the propagation direction, described by Snell's law. This change in direction is termed refraction when light passes through an interface. Reflection occurs when part or all of a wave bounces back from the interface. Both reflection and refraction can be used to form images. The study of image formation with light is called geometrical optics and involves the properties of images formed with mirrors and lenses.

Essential Knowledge 6.E.1: When light travels from one medium to another, some of the light is transmitted, some is reflected, and some is absorbed. (Qualitative understanding only.)

Learning Objective 6.E.1.1:

The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed.

[See **Science Practices 6.4 and 7.2**]

PHYSICS 2

Essential Knowledge 6.E.2: When light hits a smooth reflecting surface at an angle, it reflects at the same angle on the other side of the line perpendicular to the surface (specular reflection); this law of reflection accounts for the size and location of images seen in mirrors.

Learning Objective 6.E.2.1:

The student is able to make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface.

[See **Science Practices 6.4 and 7.2**]

PHYSICS 2

Essential Knowledge 6.E.3: When light travels across a boundary from one transparent material to another, the speed of propagation changes. At a non-normal incident angle, the path of the light ray bends closer to the perpendicular in the optically slower substance. This is called refraction.

- Snell's law relates the angles of incidence and refraction to the indices of refraction, with the ratio of the indices of refraction inversely proportional to the ratio of the speeds of propagation in the two media.
- When light travels from an optically slower substance into an optically faster substance, it bends away from the perpendicular.
- At the critical angle, the light bends far enough away from the perpendicular that it skims the surface of the material.
- Beyond the critical angle, all of the light is internally reflected.

Learning Objective 6.E.3.1:

The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.

[See **Science Practices 1.1 and 1.4**]

Learning Objective 6.E.3.2:

The student is able to plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law).

[See **Science Practices 4.1, 5.1, 5.2, and 5.3**]

Learning Objective 6.E.3.3:

The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation.

[See **Science Practices 6.4 and 7.2**]

Essential Knowledge 6.E.4: The reflection of light from surfaces can be used to form images.

- Ray diagrams are very useful for showing how and where images of objects are formed for different mirrors and how this depends upon the placement of the object. Concave and convex mirror examples should be included.
- They are also useful for determining the size of the resulting image compared to the size of the object.
- Plane mirrors, convex spherical mirrors, and concave spherical mirrors are part of this course. The construction of these ray diagrams and comparison with direct experiences are necessary.

Learning Objective 6.E.4.1:

The student is able to plan data collection strategies and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors. [See **Science Practices 3.2, 4.1, 5.1, 5.2, and 5.3**]

Learning Objective 6.E.4.2:

The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces. [See **Science Practices 1.4 and 2.2**]

Essential Knowledge 6.E.5: The refraction of light as it travels from one transparent medium to another can be used to form images.

- Ray diagrams are used to determine the relative size of object and image, the location of object and image relative to the lens, the focal length, and the real or virtual nature of the image. Converging and diverging lenses should be included as examples.

Learning Objective 6.E.5.1:

The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses. [See **Science Practices 1.4 and 2.2**]

Learning Objective 6.E.5.2:

The student is able to plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses. [See **Science Practices 3.2, 4.1, 5.1, 5.2, and 5.3**]

Enduring Understanding 6.F: Electromagnetic radiation can be modeled as waves or as fundamental particles.

One of the great discoveries of modern physics is that electromagnetic radiation, modeled in the 19th century as a classical wave, also has particle-like properties that are best captured by a hybrid model in which light is neither waves nor particles. In this hybrid, quantum model of electromagnetic spectra, photons are individual energy packets of electromagnetic waves. The discrete spectra of atoms are evidence that supports the quantum model of electromagnetic spectra. The nature of light requires that a different model of light is most appropriate at different scales. Interference is a property of waves, and radio waves traveling different paths can interfere with each other causing “dead spots” — areas of limited reception. The behavior of waves through a slit or set of slits is discussed in Enduring Understanding 6.C. Wavelengths of electromagnetic radiation range from extremely small to extremely large.

Essential Knowledge 6.F.1: Types of electromagnetic radiation are characterized by their wavelengths, and certain ranges of wavelength have been given specific names. These include (in order of increasing wavelength spanning a range from picometers to kilometers) gamma rays, x-rays, ultraviolet, visible light, infrared, microwaves, and radio waves.

Learning Objective 6.F.1.1:

The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation.
[See **Science Practices 6.4 and 7.2**]

PHYSICS 2

Essential Knowledge 6.F.2: Electromagnetic waves can transmit energy through a medium and through a vacuum.

- Electromagnetic waves are transverse waves composed of mutually perpendicular electric and magnetic fields that can propagate through a vacuum.
- The planes of these transverse waves are both perpendicular to the direction of propagation.

Learning Objective 6.F.2.1:

The student is able to describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present.
[See **Science Practice 1.1**]

PHYSICS 2

Essential Knowledge 6.F.3: Photons are individual energy packets of electromagnetic waves, with $E_{\text{photon}} = hf$, where h is Planck's constant and f is the frequency of the associated light wave.

- In the quantum model of electromagnetic radiation, the energy is emitted or absorbed in discrete energy packets called photons. Discrete spectral lines should be included as an example.
- For the short-wavelength portion of the electromagnetic spectrum, the energy per photon can be observed by direct measurement when electron emissions from matter result from the absorption of radiant energy.
- Evidence for discrete energy packets is provided by a frequency threshold for electron emission. Above the threshold, maximum kinetic energy of the emitted electrons increases with the frequency and not the intensity of absorbed radiation. The photoelectric effect should be included as an example.

Learning Objective 6.F.3.1:

The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect.

[See **Science Practice 6.4**]

Essential Knowledge 6.F.4: The nature of light requires that different models of light are most appropriate at different scales.

- The particle-like properties of electromagnetic radiation are more readily observed when the energy transported during the time of the measurement is comparable to E_{photon} .
- The wavelike properties of electromagnetic radiation are more readily observed when the scale of the objects it interacts with is comparable to or larger than the wavelength of the radiation.

Learning Objective 6.F.4.1:

The student is able to select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter.

[See **Science Practices 6.4 and 7.1**]

Enduring Understanding 6.G: All matter can be modeled as waves or as particles.

At the human scale, a thrown rock moves through space on a well-defined path. The moving object carries momentum and energy that are transferred on impact to another object or system. A splash in a pond creates a disturbance in the water, spreading in all directions and transferring energy and momentum without transferring mass. These two different forms of interaction have historically served as the metaphors that we attempt to use to explain the physical phenomena we observe. Abstracted into sophisticated mathematical models, they give highly precise predictions at the human scale. However, at other vastly different scales of size and energy, we find that neither model is an exact fit for the phenomena. Instead, we find that each of the metaphors works well to model some aspects of a situation while failing to model other aspects. The successful mathematical treatment of quantum mechanics combining mathematics derived from both metaphors goes beyond either to accurately describe phenomena at the quantum scale but leaves us without any simple visual metaphor from our everyday experience. The wave representing a particle indicates the probability of locating that particle at a particular place in space and time. This course treats these wave representations in a qualitative fashion.

Essential Knowledge 6.G.1: Under certain regimes of energy or distance, matter can be modeled as a classical particle.

Learning Objective 6.G.1.1:

The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.

[See **Science Practices 6.4 and 7.1**]

PHYSICS 2

Essential Knowledge 6.G.2: Under certain regimes of energy or distance, matter can be modeled as a wave. The behavior in these regimes is described by quantum mechanics.

- A wave model of matter is quantified by the de Broglie wavelength that increases as the momentum of the particle decreases.
- The wave property of matter was experimentally confirmed by the diffraction of electrons in the experiments of Clinton Joseph Davisson, Lester Germer, and George Paget Thomson.

PHYSICS 2

Learning Objective 6.G.2.1:

The student is able to articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the diffraction of matter interacting with a crystal, given conditions where a particle of matter has momentum corresponding to a de Broglie wavelength smaller than the separation between adjacent atoms in the crystal.

[See **Science Practice 6.1**]

Learning Objective 6.G.2.2:

The student is able to predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima) based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal. (de Broglie wavelength need not be given, so students may need to obtain it.)

[See **Science Practice 6.4**]

Big Idea 7: The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.

As developed by Newton, classical mechanics uses mathematics to deterministically calculate the motions of objects as a result of their interactions. Newton and his followers envisioned a universe in which the future could be calculated from the past. In practice, physicists soon found that only a small number of objects and interactions could be dealt with in such calculations. When a system includes many objects, such as the molecules in a gas, the mathematics of probability must be used to describe the system. Using probability, the properties of an ideal gas can be explained in terms of a small number of variables such as temperature and pressure. Furthermore, the evolution of isolated systems toward states of higher disorder can be explained using probability, giving one account of the “arrow of time.”

When the physical size of a system is scaled down to atomic size, the mathematics of probability can be used to interpret the meaning of the wave model of matter. At this scale, we find that interactions between objects are fundamentally not deterministic as Newton envisioned but can only be described by probabilities, which are calculated from a mathematical description of the wave called a wave function. This accounts for the observed wavelike properties. Although quantum physics is far from intuitive, the probabilistic description of matter at this scale has been fantastically successful in explaining the behavior of atoms and is now being applied at the frontiers of modern technology.

Enduring Understanding 7.A: The properties of an ideal gas can be explained in terms of a small number of macroscopic variables including temperature and pressure.

In a gas, all of the molecules are in constant motion, and there is a distribution of speeds. Individual speeds may be influenced by collisions with other molecules and with the walls of the container. In an ideal gas, this complicated behavior can be characterized by just a few variables: pressure (P), the combined result of the impacts of molecules; temperature (T), the average kinetic energy of the molecules; and volume (V). Statistical methods are used to relate the state variables of pressure and temperature to the distribution of velocities of the molecules. For the ideal gas model the equation $PV = nRT$ describes the relationship between the state variables.

In Maxwell's description of the connection between thermodynamic properties and atomic-scale motion, the rate of change of momentum at any surface, including that of the container that holds the gas, increases as temperature increases. Newton's second law expresses the rate of change of momentum as a force. Pressure is expressed as force per unit area.

The average kinetic energy of the gas molecules in the system is an average over a distribution of different speeds for individual molecules. The root mean square of the velocity is related to the temperature.

Essential Knowledge 7.A.1: The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum, the impulse, of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container.

Learning Objectives 7.A.1.1:

The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system.

[See **Science Practices 6.4 and 7.2**]

Learning Objectives 7.A.1.2:

Treating a gas molecule as an object (i.e., ignoring its internal structure), the student is able to analyze qualitatively the collisions with a container wall and determine the cause of pressure and at thermal equilibrium to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables.

[See **Science Practices 1.4 and 2.2**]

Essential Knowledge 7.A.2: The temperature of a system characterizes the average kinetic energy of its molecules.

- The average kinetic energy of the system is an average over the many different speeds of the molecules in the system that can be described by a distribution curve.
- The root mean square speed corresponding to the average kinetic energy for a specific gas at a given temperature can be obtained from this distribution.

Learning Objective 7.A.2.1:

The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system.
[See **Science Practice 7.1**]

Learning Objective 7.A.2.2:

The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.
[See **Science Practice 7.1**]

Essential Knowledge 7.A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V) are related by the equation $PV = nRT$.

Learning Objective:

7.A.3.1 The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero.
[See **Science Practices 6.4 and 7.2**]

Learning Objective 7.A.3.2:

The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.
[See **Science Practices 3.2 and 4.2**]

Learning Objective 7.A.3.3

The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$.
[See **Science Practice 5.1**]

Enduring Understanding 7.B: The tendency of isolated systems to move toward states with higher disorder is described by probability.

The transfers of energy that occur in thermal processes depend on a very large number of very small-scale (molecular and atomic) interactions, and thus these energy transfers are best described by the mathematics of probability. When parts of an isolated system initially at different temperatures interact, higher momentum particles are more likely to be involved in more collisions. Consequently, conservation of momentum makes it more likely that kinetic energy will be transferred from higher energy to lower energy particles, reducing both the number of high energy particles and the number of low energy particles until, after many collisions, all interacting parts of a system will arrive at the same temperature. The amount of thermal energy needed to change the temperature of a given part of a system will depend on the total mass of that part of the system and on the difference between its initial and final temperatures. Neither energy conservation nor momentum conservation laws have any preferred direction in time, yet large-scale processes always tend toward equilibrium and not toward disequilibrium. The second law of thermodynamics describes the tendency of large systems to move toward states with higher disorder. A new state function, entropy, can be defined, and it depends only on the configuration of the system and not on how the system arrived in that configuration. Unlike energy, entropy is not conserved but instead always increases for irreversible processes in closed systems.

Essential Knowledge 7.B.1: The approach to thermal equilibrium is a probability process.

- The amount of thermal energy needed to change the temperature of a system of particles depends both on the mass of the system and on the temperature change of the system.
- The details of the energy transfer depend upon interactions at the molecular level.
- Since higher momentum particles will be involved in more collisions, energy is most likely to be transferred from higher to lower energy particles. The most likely state after many collisions is that both systems of particles have the same temperature.

Learning Objective 7.B.1.1:

The student is able to construct an explanation, based on atomic-scale interactions and probability, of how a system approaches thermal equilibrium when energy is transferred to it or from it in a thermal process.

[See **Science Practice 6.2**]

Essential Knowledge 7.B.2: The second law of thermodynamics describes the change in entropy for reversible and irreversible processes. Only a qualitative treatment is considered in this course.

- Entropy, like temperature, pressure, and internal energy, is a state function whose value depends only on the configuration of the system at a particular instant and not on how the system arrived at that configuration.
- Entropy can be described as a measure of the disorder of a system or of the unavailability of some system energy to do work.
- The entropy of a closed system never decreases, i.e., it can stay the same or increase.
- The total entropy of the universe is always increasing.

Learning Objective 7.B.2.1:

The student is able to connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes. [See **Science Practice 7.1**]

Enduring Understanding 7.C: At the quantum scale, matter is described by a wave function, which leads to a probabilistic description of the microscopic world.

This enduring understanding follows on the heels of Enduring Understandings 1.D and 6.G. Students need to be aware that classical physics cannot describe everything and that there are new, nonclassical ideas that must be addressed for a more complete understanding of the physical world.

The dynamic properties of quantum mechanical systems are expressed in terms of probability distributions. At this scale, we find that interactions between objects are fundamentally not deterministic as Newton envisioned but can only be described by probabilities, which are calculated from the wave function. This gives rise to observed wave properties of matter. One such property is that an electron in an atom has a discrete set of possible energy states. The energy states of the atom can be described in terms of allowable energy transitions due to emission or absorption of photons, processes that are determined by probability. These phenomena are the basis of lasers. The spontaneous

radioactive decay of an individual nucleus is described by probability as well. Balancing of mass and charge in nuclear equations can be used to determine missing species in the equation and to explain pair production and annihilation. These ideas can also be used to understand fission and fusion, one current and one possible future source of energy.

Essential Knowledge 7.C.1: The probabilistic description of matter is modeled by a wave function, which can be assigned to an object and used to describe its motion and interactions. The absolute value of the wave function is related to the probability of finding a particle in some spatial region. (Qualitative treatment only, using graphical analysis.)

Learning Objective 7.C.1.1:

The student is able to use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region.
[See **Science Practice 1.4**]

PHYSICS 2

Essential Knowledge 7.C.2: The allowed states for an electron in an atom can be calculated from the wave model of an electron.

- The allowed electron energy states of an atom are modeled as standing waves. Transitions between these levels, due to emission or absorption of photons, are observable as discrete spectral lines.
- The de Broglie wavelength of an electron can be calculated from its momentum, and a wave representation can be used to model discrete transitions between energy states as transitions between standing waves.

Learning Objective 7.C.2.1:

The student is able to use a standing wave model in which an electron orbit circumference is an integer multiple of the de Broglie wavelength to give a qualitative explanation that accounts for the existence of specific allowed energy states of an electron in an atom.
[See **Science Practice 1.4**]

PHYSICS 2

Essential Knowledge 7.C.3: The spontaneous radioactive decay of an individual nucleus is described by probability.

- a. In radioactive decay processes, we cannot predict when any one nucleus will undergo a change; we can only predict what happens on the average to a large number of identical nuclei.
- b. In radioactive decay, mass and energy are interrelated, and energy is released in nuclear processes as kinetic energy of the products or as electromagnetic energy.
- c. The time for half of a given number of radioactive nuclei to decay is called the half-life.
- d. Different unstable elements and isotopes have vastly different half-lives, ranging from small fractions of a second to billions of years.

Learning Objective 7.C.3.1:

The student is able to predict the number of radioactive nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay.

[See **Science Practice 6.4**]

Essential Knowledge 7.C.4: Photon emission and absorption processes are described by probability.

- a. An atom in a given energy state may absorb a photon of the right energy and move to a higher energy state (stimulated absorption).
- b. An atom in an excited energy state may jump spontaneously to a lower energy state with the emission of a photon (spontaneous emission).
- c. Spontaneous transitions to higher energy states have a very low probability but can be stimulated to occur. Spontaneous transitions to lower energy states are highly probable.
- d. When a photon of the right energy interacts with an atom in an excited energy state, it may stimulate the atom to make a transition to a lower energy state with the emission of a photon (stimulated emission). In this case, both photons have the same energy and are in phase and moving in the same direction.

Learning Objective 7.C.4.1:

The student is able to construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. [For questions addressing stimulated emission, students will not be expected to recall the details of the process, such as the fact that the emitted photons have the same frequency and phase as the incident photon; but given a representation of the process, students are expected to make inferences such as figuring out from energy conservation that since the atom loses energy in the process, the emitted photons taken together must carry more energy than the incident photon.] [See **Science Practices 1.1 and 1.2**]

Science Practices for AP Physics 1 and 2

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

The real world is extremely complex. When physicists describe and explain phenomena, they try to simplify real objects, systems, and processes to make the analysis manageable. These simplifications or models are used to predict how new phenomena will occur. A simple model may treat a system as an object, neglecting the system's internal structure and behavior. More complex models are models of a system of objects, such as an ideal gas. A process can be simplified, too; free fall is an example of a simplified process, when we consider only the interaction of the object with the Earth. Models can be both conceptual and mathematical. Ohm's law is an example of a mathematical model, while the model of a current as a steady flow of charged particles is a conceptual model (the charged particles move randomly with some net motion [drift] of particles in a particular direction). Basically, to make a good model, one needs to identify a set of the most important characteristics of a phenomenon or system that may simplify analysis. Inherent in the construction of models that physicists invent is the use of representations. Examples of representations used to model introductory physics are pictures, motion diagrams, force diagrams, graphs, energy bar charts, and ray diagrams. Mathematical representations such as equations are another example. Representations help in analyzing phenomena, making predictions, and communicating ideas. An example here is using a motion diagram and a force diagram to develop the mathematical expression of Newton's second law in component form to solve a dynamics problem.

- 1.1 The student can *create representations and models* of natural or man-made phenomena and systems in the domain.
- 1.2 The student can *describe representations and models* of natural or man-made phenomena and systems in the domain.
- 1.3 The student can *refine representations and models* of natural or man-made phenomena and systems in the domain.
- 1.4 The student can *use representations and models* to analyze situations or solve problems qualitatively and quantitatively.
- 1.5 The student can *reexpress key elements of natural phenomena across multiple representations* in the domain.

Science Practice 2: The student can use mathematics appropriately.

Physicists commonly use mathematical representations to describe and explain phenomena as well as to solve problems. When students work with these representations, we want them to understand the connections between the mathematical description, the physical phenomena, and the concepts represented in the mathematical descriptions. When using equations or mathematical representations, students need to be able to justify why using a particular equation to analyze a particular situation is useful as well as to be aware of the conditions under which the equations/mathematical representations can be used. Students tend to rely too much on mathematical representations. When solving a problem, they need to be able to describe the problem situation in multiple ways, including picture representations, force diagrams, and so on, and then choose an appropriate mathematical representation, instead of first choosing a formula whose variables match the givens in the problem. In addition, students should be able to work with the algebraic form of the equation before they substitute values. They also should be able to evaluate the equation(s) and the answer obtained in terms of units and limiting case analysis: Does the equation lead to results that can be predicted qualitatively if one of the quantities in the problem is zero or infinity? They should be able to translate between functional relations in equations (proportionalities, inverse proportionalities, etc.) and cause-and-effect relations in the physical world. They should also be able to evaluate the numerical result in terms of whether it makes sense. For example, obtaining 35 m/s^2 for the acceleration of a bus — about four times the acceleration of a freely falling object — should raise flags in students' minds. In many physics situations, simple mathematical routines may be needed to arrive at a result even though they are not the focus of a learning objective.

- 2.1 The student can *justify the selection of a mathematical routine* to solve problems.
- 2.2 The student can *apply mathematical routines* to quantities that describe natural phenomena.
- 2.3 The student can *estimate numerically quantities* that describe natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

Research scientists pose and answer meaningful questions. Students may easily miss this point since, depending on how a science class is taught, it may seem that science is about compiling and passing down a large body of known facts (e.g., the acceleration of free-falling objects is 9.8 m/s^2 ; $\vec{a} = \frac{\sum \vec{F}}{m}$). At the opposite end of the spectrum, some students may believe that science can solve every important societal problem. Thus, helping students learn how to pose, refine, and evaluate scientific questions is an important instructional and cognitive goal, albeit a difficult skill to learn. Even within a simple physics topic, posing a scientific question can be difficult. When asked what they might want to find out about a simple pendulum, some students may ask, “How high does it swing?” Although this is a starting point from which a teacher may build, students need to be guided toward refining “fuzzy” questions and relating questions to relevant models and theories. As a first step to refining this question, students might first consider in what ways one can measure physical quantities relevant to the pendulum’s motion, leading to a discussion of time, angle (amplitude), and mass. Follow-up discussions can lead to how one goes about evaluating questions such as, “Upon what does the period of a simple pendulum depend?” by designing and carrying out experiments, and then evaluating data and findings.

- 3.1 The student can *pose scientific questions*.
- 3.2 The student can *refine scientific questions*.
- 3.3 The student can *evaluate scientific questions*.

Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question.

[Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction, and/or archived data.]

Scientific questions can range in scope from broad to narrow, as well as in specificity, from determining influencing factors and/or causes to determining mechanism. The question posed will determine the type of data to be collected and will influence the plan for collecting data. An example of a broad question is, “What caused the extinction of the dinosaurs?” whereas a narrow one is, “Upon what does the period of a simple pendulum depend?” Both questions ask for influencing factors and/or causes; an answer to the former might be “An asteroid collision with Earth caused the extinction of the dinosaurs,” whereas an answer to the latter might be “The period depends on the mass and length of the pendulum.” To test the cause of the pendulum’s period, an experimental plan might vary mass and length to ascertain if these factors indeed influence the period of a pendulum, taking care to control variables so as to determine whether one factor, the other, or both influence the period. A question could be posed to ask about mechanism, e.g., “How did the dinosaurs become extinct?” or “How does the period of a simple pendulum depend on the mass and length?” In the second question, the object is to determine a mathematical relationship between period, mass, and length of a pendulum. Designing and improving experimental designs and/or data collection strategies is a learned skill. A class discussion among students in a pendulum experiment might find some who measured the time for a single round-trip, while others timed 10 round-trips and divided by 10. Such discussions can reveal issues of measurement uncertainty and assumptions about the motion. Students need to understand that the result of collecting and using data to determine a numerical answer to a question is best thought of as an interval, not a single number. This interval, the experimental uncertainty, is due to a combination of uncertainty in the instruments used and the process of taking the measurement. Although detailed error analysis is not necessary to convey this pivotal idea, it is important that students make some reasoned estimate of the interval within which they know the value of a measured data point and express their results in a way that makes this clear.

- 4.1 The student can *justify the selection of the kind of data* needed to answer a particular scientific question.
- 4.2 The student can *design a plan* for collecting data to answer a particular scientific question.
- 4.3 The student can *collect data* to answer a particular scientific question.
- 4.4 The student can *evaluate sources of data* to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

Students often think that to make a graph they need to connect the data points or that the best-fit function is always linear. Thus, it is important that they can construct a best-fit curve even for data that do not fit a linear relationship (such as quadratic or exponential functions).

Students should be able to represent data points as intervals whose size depends on the experimental uncertainty. After students find a pattern in the data, they need to ask why this pattern is present and try to explain it using the knowledge that they have. When dealing with a new phenomenon, they should be able to devise a testable explanation of the pattern if possible (see **Science Practice 6.4**). It is important that students understand that instruments do not produce exact measurements and learn what steps they can take to decrease the uncertainty. Students should be able to design a second experiment to determine the same quantity and then check for consistency across the two measurements, comparing two results by writing them both as intervals and not as single, absolute numbers. Finally, students should be able to revise their reasoning based on the new data, data that for some may appear anomalous.

- 5.1 The student can *analyze data* to identify patterns or relationships.
- 5.2 The student can *refine observations and measurements* based on data analysis.
- 5.3 The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories.

Scientific explanations may specify a cause-and-effect relationship between variables or describe a mechanism through which a particular phenomenon occurs.

Newton's second law, expressed as $\vec{a} = \frac{\sum \vec{F}}{m}$, gives the acceleration

observed when a given combination of forces is exerted on an object with a certain mass. Liquids dry up because randomly moving molecules can leave liquids if their kinetic energy is higher than the negative potential energy of interaction between them and the liquid. A scientific explanation, accounting for an observed phenomenon, needs to be experimentally testable. One should be able to use it to make predictions about a new phenomenon. A theory uses a unified approach to account for a large set of phenomena and gives accounts that are consistent with multiple experimental outcomes within the range of applicability of the theory. Examples of theories in physics include kinetic molecular theory, quantum theory, atomic theory, etc. Students should understand the difference between explanations and theories.

In this framework the word “claim” means any answer that a student provides except those that constitute direct and simple observational evidence. To say that all objects fall down is not a claim, but to say that all objects fall with the same acceleration is a claim, as one would need to back it up with evidence and a chain of reasoning. Students should be prepared to offer evidence, to construct reasoned arguments for their claim from the evidence, and to use the claim or explanation to make predictions. A prediction states the expected outcome of a particular experimental design based on an explanation or a claim under scrutiny. Consider the claim that current is directly proportional to potential difference across conductors based on data from an experiment varying voltage across a resistor and measuring current through it. The claim can be tested by connecting other resistors or lightbulbs in the circuit, measuring the voltage, using the linear relationship to predict the current, and comparing the predicted and measured current. This procedure tests the claim. Students should be able to design experiments to test alternative explanations of phenomena by comparing predicted outcomes. For example, students may think that liquids dry because air absorbs moisture. To test the claim they can design an experiment in which the same liquid dries in two conditions: in open air and in a vacuum jar. If the claim is correct, the liquid should dry faster in air. If the outcome does not match the prediction, the explanation is likely to be false. By contrast, if the outcome confirms the prediction, it only means that this experiment does not disprove the explanation; alternate explanations of the given outcome can always be formulated. Looking for experiments that can reject explanations and claims is at the heart of science.

- 6.1 The student can *justify claims with evidence*.
- 6.2 The student can *construct explanations of phenomena based on evidence* produced through scientific practices.
- 6.3 The student can *articulate the reasons that scientific explanations and theories are refined or replaced*.
- 6.4 The student can *make claims and predictions about natural phenomena* based on scientific theories and models.
- 6.5 The student can *evaluate alternative scientific explanations*.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

Students should have the opportunity to transfer their learning across disciplinary boundaries so that they are able to link, synthesize, and apply the ideas they learn across the sciences and mathematics. Research on how

people learn indicates that providing multiple contexts to which major ideas apply facilitates transfer; this allows students to bundle knowledge in memory together with the multiple contexts to which it applies. Students should also be able to recognize seemingly appropriate contexts to which major concepts and ideas do not apply. After learning various conservation laws in the context of mechanics, students should be able to describe what the concept of conservation means in physics and extend the idea to other contexts. For example, what might conservation of energy mean at high-energy scales with particle collisions, where Einstein's mass–energy equivalence plays a major role? What does conservation of energy mean when constructing or evaluating arguments about global warming? Another context in which students may apply ideas from physics across vast spatial and time scales is the origin of human life on Earth coupled with the notion of extraterrestrial intelligent life. If one views the age of the Earth in analogy to a year of time (see Ritger & Cummins, 1991) with the Earth formed on January 1, then life began on Earth around April 5; multicellular organisms appeared on November 6; mammals appeared on December 23. Perhaps most amazingly, humans appeared on December 31 just 28 minutes before midnight. What are the implications of this for seeking intelligent life outside our solar system? What is a reasonable estimate of the probability of finding intelligent life on an earthlike planet that scientists might discover through astronomical observations, and how does one go about making those estimates? Although students are not expected to answer these very complex questions after a single AP science course, they should be able to talk intelligently about them using the concepts they learned.

- 7.1 The student can *connect phenomena and models* across spatial and temporal scales.
- 7.2 The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

References

The AP course and exam development process relies on groups of nationally renowned subject-matter experts in each discipline, including professionals in secondary and postsecondary education as well as from professional organizations. These experts ensure that AP courses and exams reflect the most up-to-date information available, that the courses and exams are appropriate for a college-level course, and that student proficiency is assessed properly. To help ensure that the knowledge, skills, and abilities identified in the course and exam are articulated in a manner that will serve as a strong foundation for both curriculum and assessment design, the subject-matter experts for AP Physics 1: Algebra-based and AP Physics 2: Algebra-based utilized principles and tools from the following works.

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- Riconscente, M. M., R. J. Mislevy, and L. Hamel. 2005. *An Introduction to PADI Task Templates* (PADI Technical Report 3). Menlo Park, CA: SRI International and University of Maryland. Retrieved May 1, 2006, from http://padi.sri.com/downloads/TR3_Templates.pdf
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Appendix A: AP Physics 1 Concepts at a Glance

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Enduring Understanding 1.A: The internal structure of a system determines many properties of the system.	Essential Knowledge 1.A.1: A system is an object or a collection of objects. Objects are treated as having no internal structure.
	Essential Knowledge 1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an <i>object</i> .
Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.	Essential Knowledge 1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
	Essential Knowledge 1.B.2: There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
	Essential Knowledge 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
Enduring Understanding 1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.	Essential Knowledge 1.C.1: Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems.
	Essential Knowledge 1.C.2: Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.
	Essential Knowledge 1.C.3: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
Enduring Understanding 1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.	Essential Knowledge 1.E.2: Matter has a property called resistivity.

Big Idea 2: Fields existing in space can be used to explain interactions.

Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.	Essential Knowledge 2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.
Enduring Understanding 2.B: A gravitational field is caused by an object with mass.	Essential Knowledge 2.B.1: A gravitational field $\vec{g}$ at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.
	Essential Knowledge 2.B.2: The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.	Essential Knowledge 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	Essential Knowledge 3.A.2: Forces are described by vectors.
	Essential Knowledge 3.A.3: A force exerted on an object is always due to the interaction of that object with another object.
	Essential Knowledge 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.
Enduring Understanding 3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\Sigma \vec{F}}{m}$.	Essential Knowledge 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
	Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
	Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum, mass-spring oscillator.

Enduring Understanding 3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.	Essential Knowledge 3.C.1: Gravitational force describes the interaction of one object that has mass with another object that has mass.
	Essential Knowledge 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
	Essential Knowledge 3.C.4: Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).
Enduring Understanding 3.D: A force exerted on an object can change the momentum of the object.	Essential Knowledge 3.D.1: The change in momentum of an object is a vector in the direction of the net force exerted on the object.
	Essential Knowledge 3.D.2: The change in momentum of an object occurs over a time interval.
Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.	Essential Knowledge 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted.
Enduring Understanding 3.F: A force exerted on an object can cause a torque on that object.	Essential Knowledge 3.F.1: Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.
	Essential Knowledge 3.F.2: The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis.
	Essential Knowledge 3.F.3: A torque exerted on an object can change the angular momentum of an object.
Enduring Understanding 3.G: Certain types of forces are considered fundamental.	Essential Knowledge 3.G.1: Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

Big Idea 4: Interactions between systems can result in changes in those systems.

Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\Sigma \vec{F}}{m}.$	Essential Knowledge 4.A.1: The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.
	Essential Knowledge 4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
	Essential Knowledge 4.A.3: Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.

Enduring Understanding 4.B: Interactions with other objects or systems can change the total linear momentum of a system.	Essential Knowledge 4.B.1: The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.
	Essential Knowledge 4.B.2: The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.
Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.	Essential Knowledge 4.C.1: The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.
	Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.
Enduring Understanding 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.	Essential Knowledge 4.D.1: Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis.
	Essential Knowledge 4.D.2: The angular momentum of a system may change due to interactions with other objects or systems.
	Essential Knowledge 4.D.3: The change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding 5.A: Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.	Essential Knowledge 5.A.1: A system is an object or a collection of objects. The objects are treated as having no internal structure.
	Essential Knowledge 5.A.2: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
	Essential Knowledge 5.A.3: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.
	Essential Knowledge 5.A.4: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.

Enduring Understanding 5.B: The energy of a system is conserved.	Essential Knowledge 5.B.1: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.
	Essential Knowledge 5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [Physics 1: includes mass-spring oscillators and simple pendulums. Physics 2: includes charged object in electric fields and examining changes in internal energy with changes in configuration.]
	Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
	Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.
	Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. [A piston filled with gas getting compressed or expanded is treated in Physics 2 as a part of thermodynamics.]
Enduring Understanding 5.C: The electric charge of a system is conserved.	Essential Knowledge 5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]
	Essential Knowledge 5.C.3: Kirchhoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Physics 1: covers circuits with resistors in series, with at most one parallel branch, one battery only. Physics 2: includes capacitors in steady-state situations. For circuits with capacitors, situations should be limited to open circuit, just after circuit is closed, and a long time after the circuit is closed.]

Enduring Understanding 5.D: The linear momentum of a system is conserved.	Essential Knowledge 5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
	Essential Knowledge 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
	Essential Knowledge 5.D.3: The velocity of the center of mass of the system cannot be changed by an interaction within the system. [Physics 1: includes no calculations of centers of mass; the equation is not provided until Physics 2. However, without doing calculations, Physics 1 students are expected to be able to locate the center of mass of highly symmetric mass distributions, such as a uniform rod or cube of uniform density, or two spheres of equal mass.]
Enduring Understanding 5.E: The angular momentum of a system is conserved.	Essential Knowledge 5.E.1: If the net external torque exerted on the system is zero, the angular momentum of the system does not change.
	Essential Knowledge 5.E.2: The angular momentum of a system is determined by the locations and velocities of the objects that make up the system. The rotational inertia of an object or system depends upon the distribution of mass within the object or system. Changes in the radius of a system or in the distribution of mass within the system result in changes in the system's rotational inertia, and hence in its angular velocity and linear speed for a given angular momentum. Examples should include elliptical orbits in an Earth-satellite system. Mathematical expressions for the moments of inertia will be provided where needed. Students will not be expected to know the parallel axis theorem.

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.	Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.
	Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.
	Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.
	Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.

Enduring Understanding 6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.	Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.
	Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.
	Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.
	Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.
Enduring Understanding 6.D: Interference and superposition lead to standing waves and beats.	Essential Knowledge 6.D.1: Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.
	Essential Knowledge 6.D.2: Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.
	Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string and sound waves in both closed and open tubes.
	Essential Knowledge 6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.
	Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency.

Appendix B: AP Physics 2 Concepts at a Glance

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Enduring Understanding 1.A: The internal structure of a system determines many properties of the system.	Essential Knowledge 1.A.2: Fundamental particles have no internal structure.
	Essential Knowledge 1.A.3: Nuclei have internal structures that determine their properties.
	Essential Knowledge 1.A.4: Atoms have internal structures that determine their properties.
	Essential Knowledge 1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an <i>object</i> .
Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.	Essential Knowledge 1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
	Essential Knowledge 1.B.2: There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
	Essential Knowledge 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
Enduring Understanding 1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.	Essential Knowledge 1.C.4: In certain processes, mass can be converted to energy and energy can be converted to mass according to $E = mc^2$, the equation derived from the theory of special relativity.
Enduring Understanding 1.D: Classical mechanics cannot describe all properties of objects.	Essential Knowledge 1.D.1: Objects classically thought of as particles can exhibit properties of waves.
	Essential Knowledge 1.D.2: Certain phenomena classically thought of as waves can exhibit properties of particles.
	Essential Knowledge 1.D.3: Properties of space and time cannot always be treated as absolute.

Enduring Understanding 1.E: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.	Essential Knowledge 1.E.1: Matter has a property called density.
	Essential Knowledge 1.E.2: Matter has a property called resistivity.
	Essential Knowledge 1.E.3: Matter has a property called thermal conductivity.
	Essential Knowledge 1.E.4: Matter has a property called electric permittivity.
	Essential Knowledge 1.E.5: Matter has a property called magnetic permeability.
	Essential Knowledge 1.E.6: Matter has a property called magnetic dipole moment.

Big Idea 2: Fields existing in space can be used to explain interactions.

Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.	Essential Knowledge 2.A.1: A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.
	Essential Knowledge 2.A.2: A scalar field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a scalar. In Physics 2, this should include electric potential.
Enduring Understanding 2.C: An electric field is caused by an object with electric charge.	Essential Knowledge 2.C.1: The magnitude of the electric force F exerted on an object with electric charge q by an electric field $\vec{E} = q\vec{E}$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.
	Essential Knowledge 2.C.2: The magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field. This includes positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.
	Essential Knowledge 2.C.3: The electric field outside a spherically symmetric charged object is radial, and its magnitude varies as the inverse square of the radial distance from the center of that object. Electric field lines are not in the curriculum. Students will be expected to rely only on the rough intuitive sense underlying field lines, wherein the field is viewed as analogous to something emanating uniformly from a source.

	Essential Knowledge 2.C.4: The electric field around dipoles and other systems of electrically charged objects (that can be modeled as point objects) is found by vector addition of the field of each individual object. Electric dipoles are treated qualitatively in this course as a teaching analogy to facilitate student understanding of magnetic dipoles.
	Essential Knowledge 2.C.5: Between two oppositely charged parallel plates with uniformly distributed electric charge, at points far from the edges of the plates, the electric field is perpendicular to the plates and is constant in both magnitude and direction.
Enduring Understanding 2.D: A magnetic field is caused by a magnet or a moving electrically charged object. Magnetic fields observed in nature always seem to be produced either by moving charged objects or by magnetic dipoles or combinations of dipoles and never by single poles.	Essential Knowledge 2.D.1: The magnetic field exerts a force on a moving electrically charged object. That magnetic force is perpendicular to the direction of velocity of the object and to the magnetic field and is proportional to the magnitude of the charge, the magnitude of the velocity, and the magnitude of the magnetic field. It also depends on the angle between the velocity and the magnetic field vectors. Treatment is quantitative for angles of 0°, 90°, or 180° and qualitative for other angles.
	Essential Knowledge 2.D.2: The magnetic field vectors around a straight wire that carries electric current are tangent to concentric circles centered on that wire. The field has no component toward the current-carrying wire.
	Essential Knowledge 2.D.3: A magnetic dipole placed in a magnetic field, such as the ones created by a magnet or the Earth, will tend to align with the magnetic field vector.
	Essential Knowledge 2.D.4: Ferromagnetic materials contain magnetic domains that are themselves magnets.
Enduring Understanding 2.E: Physicists often construct a map of isolines connecting points of equal value for some quantity related to a field and use these maps to help visualize the field.	Essential Knowledge 2.E.1: Isolines on a topographic (elevation) map describe lines of approximately equal gravitational potential energy per unit mass (gravitational equipotential). As the distance between two different isolines decreases, the steepness of the surface increases. [Contour lines on topographic maps are useful teaching tools for introducing the concept of equipotential lines. Students are encouraged to use the analogy in their answers when explaining gravitational and electrical potential and potential differences.]
	Essential Knowledge 2.E.2: Isolines in a region where an electric field exists represent lines of equal electric potential, referred to as equipotential lines.
	Essential Knowledge 2.E.3: The average value of the electric field in a region equals the change in electric potential across that region divided by the change in position (displacement) in the relevant direction.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.	Essential Knowledge 3.A.2: Forces are described by vectors.
	Essential Knowledge 3.A.3: A force exerted on an object is always due to the interaction of that object with another object.
	Essential Knowledge 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.
Enduring Understanding 3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using $\vec{a} = \frac{\sum \vec{F}}{m}$.	Essential Knowledge 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
	Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
Enduring Understanding 3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.	Essential Knowledge 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
	Essential Knowledge 3.C.3: A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.
	Essential Knowledge 3.C.4: Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).
Enduring Understanding 3.G: Certain types of forces are considered fundamental.	Essential Knowledge 3.G.1: Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.
	Essential Knowledge 3.G.2: Electromagnetic forces are exerted at all scales and can dominate at the human scale.
	Essential Knowledge 3.G.3: The strong force is exerted at nuclear scales and dominates the interactions of nucleons.

Big Idea 4: Interactions between systems can result in changes in those systems.

Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.	Essential Knowledge 4.C.3: Energy is transferred spontaneously from a higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat.
	Essential Knowledge 4.C.4: Mass can be converted into energy, and energy can be converted into mass.
Enduring Understanding 4.E: The electric and magnetic properties of a system can change in response to the presence of, or changes in, other objects or systems.	Essential Knowledge 4.E.1: The magnetic properties of some materials can be affected by magnetic fields at the system. Students should focus on the underlying concepts and not the use of the vocabulary.
	Essential Knowledge 4.E.2: Changing magnetic flux induces an electric field that can establish an induced emf in a system.
	Essential Knowledge 4.E.3: The charge distribution in a system can be altered by the effects of electric forces produced by a charged object.
	Essential Knowledge 4.E.4: The resistance of a resistor, and the capacitance of a capacitor, can be understood from the basic properties of electric fields and forces as well as the properties of materials and their geometry.
	Essential Knowledge 4.E.5: The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding 5.B: The energy of a system is conserved.	Essential Knowledge 5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [Physics 1: includes mass-spring oscillators and simple pendulums. Physics 2: includes charged object in electric fields and examining changes in internal energy with changes in configuration.]
	Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.
	Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. [A piston filled with gas getting compressed or expanded is treated in Physics 2 as a part of thermodynamics.]
	Essential Knowledge 5.B.6: Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.
	Essential Knowledge 5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.
	Essential Knowledge 5.B.8: Energy transfer occurs when photons are absorbed or emitted, for example, by atoms or nuclei.
	Essential Knowledge 5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]
	Essential Knowledge 5.B.10: Bernoulli's equation describes the conservation of energy in fluid flow.
	Essential Knowledge 5.B.11: Beyond the classical approximation, mass is actually part of the internal energy of an object or system with $E = mc^2$.

Enduring Understanding 5.C: The electric charge of a system is conserved.	Essential Knowledge 5.C.1: Electric charge is conserved in nuclear and elementary particle reactions, even when elementary particles are produced or destroyed. Examples should include equations representing nuclear decay.
	Essential Knowledge 5.C.2: The exchange of electric charges among a set of objects in a system conserves electric charge.
	Essential Knowledge 5.C.3: Kirchhoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Physics 1: covers circuits with resistors in series, with at most one parallel branch, one battery only. Physics 2: includes capacitors in steady-state situations. For circuits with capacitors, situations should be limited to open circuit, just after circuit is closed, and a long time after the circuit is closed.]
Enduring Understanding 5.D: The linear momentum of a system is conserved.	Essential Knowledge 5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
	Essential Knowledge 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
	Essential Knowledge 5.D.3: The velocity of the center of mass of the system cannot be changed by an interaction within the system. [Physics 1: includes no calculations of centers of mass; the equation is not provided until Physics 2. However, without doing calculations, Physics 1 students are expected to be able to locate the center of mass of highly symmetric mass distributions, such as a uniform rod or cube of uniform density, or two spheres of equal mass.]
Enduring Understanding 5.F: Classically, the mass of a system is conserved.	Essential Knowledge 5.F.1: The continuity equation describes conservation of mass flow rate in fluids. Examples should include volume rate of flow and mass flow rate.
Enduring Understanding 5.G: Nucleon number is conserved.	Essential Knowledge 5.G.1: The possible nuclear reactions are constrained by the law of conservation of nucleon number.

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.	Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.
	Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.
Enduring Understanding 6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.	Essential Knowledge 6.B.3: A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave.
Enduring Understanding 6.C: Only waves exhibit interference and diffraction.	Essential Knowledge 6.C.1: When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.
	Essential Knowledge 6.C.2: When waves pass through an opening whose dimensions are comparable to the wavelength, a diffraction pattern can be observed.
	Essential Knowledge 6.C.3: When waves pass through a set of openings whose spacing is comparable to the wavelength, an interference pattern can be observed. Examples should include monochromatic double-slit interference.
	Essential Knowledge 6.C.4: When waves pass by an edge, they can diffract into the “shadow region” behind the edge. Examples should include hearing around corners, but not seeing around them, and water waves bending around obstacles.
Enduring Understanding 6.E: The direction of propagation of a wave such as light may be changed when the wave encounters an interface between two media.	Essential Knowledge 6.E.1: When light travels from one medium to another, some of the light is transmitted, some is reflected, and some is absorbed. (Qualitative understanding only.)
	Essential Knowledge 6.E.2: When light hits a smooth reflecting surface at an angle, it reflects at the same angle on the other side of the line perpendicular to the surface (specular reflection); this law of reflection accounts for the size and location of images seen in mirrors.

Enduring Understanding 6.E: The direction of propagation of a wave such as light may be changed when the wave encounters an interface between two media.	Essential Knowledge 6.E.3: When light travels across a boundary from one transparent material to another, the speed of propagation changes. At a non-normal incident angle, the path of the light ray bends closer to the perpendicular in the optically slower substance. This is called refraction.
	Essential Knowledge 6.E.4: The reflection of light from surfaces can be used to form images.
	Essential Knowledge 6.E.5: The refraction of light as it travels from one transparent medium to another can be used to form images.
Enduring Understanding 6.F: Electromagnetic radiation can be modeled as waves or as fundamental particles.	Essential Knowledge 6.F.1: Types of electromagnetic radiation are characterized by their wavelengths, and certain ranges of wavelength have been given specific names. These include (in order of increasing wavelength spanning a range from picometers to kilometers) gamma rays, x-rays, ultraviolet, visible light, infrared, microwaves, and radio waves.
	Essential Knowledge 6.F.2: Electromagnetic waves can transmit energy through a medium and through a vacuum.
	Essential Knowledge 6.F.3: Photons are individual energy packets of electromagnetic waves, with $E_{\text{photon}} = hf$, where h is Planck's constant and f is the frequency of the associated light wave.
	Essential Knowledge 6.F.4: The nature of light requires that different models of light are most appropriate at different scales.
Enduring Understanding 6.G: All matter can be modeled as waves or as particles.	Essential Knowledge 6.G.1: Under certain regimes of energy or distance, matter can be modeled as a classical particle.
	Essential Knowledge 6.G.2: Under certain regimes of energy or distance, matter can be modeled as a wave. The behavior in these regimes is described by quantum mechanics.

Big Idea 7: The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.

Enduring Understanding 7A: The properties of an ideal gas can be explained in terms of a small number of macroscopic variables including temperature and pressure.	Essential Knowledge 7A.1: The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum, the impulse, of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container.
	Essential Knowledge 7A.2: The temperature of a system characterizes the average kinetic energy of its molecules.
	Essential Knowledge 7A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V), are related by the equation $PV = nRT$.
Enduring Understanding 7B: The tendency of isolated systems to move toward states with higher disorder is described by probability.	Essential Knowledge 7B.1: The approach to thermal equilibrium is a probability process.
	Essential Knowledge 7B.2: The second law of thermodynamics describes the change in entropy for reversible and irreversible processes. Only a qualitative treatment is considered in this course.
Enduring Understanding 7C: At the quantum scale, matter is described by a wave function, which leads to a probabilistic description of the microscopic world.	Essential Knowledge 7C.1: The probabilistic description of matter is modeled by a wave function, which can be assigned to an object and used to describe its motion and interactions. The absolute value of the wave function is related to the probability of finding a particle in some spatial region. (Qualitative treatment only, using graphical analysis.)
	Essential Knowledge 7C.2: The allowed states for an electron in an atom can be calculated from the wave model of an electron.
	Essential Knowledge 7C.3: The spontaneous radioactive decay of an individual nucleus is described by probability.
	Essential Knowledge 7C.4: Photon emission and absorption processes are described by probability.

Appendix C: Developing Big Ideas from Foundational Physics Principles

The table below helps illustrate how to make connections across the curriculum framework by developing big ideas from the foundational physics principles.

Physics 1 Principles	Big Ideas
Kinematics (1D and 2D)	3
Dynamics: Newton's Laws	1, 2, 3, 4
Circular Motion and Universal Law of Gravitation	1, 2, 3, 4
Simple Harmonic Motion: Simple Pendulum and Mass-Spring Systems	3, 5
Impulse, Linear Momentum, and Conservation of Linear Momentum: Collisions	3, 4, 5
Work, Energy, and Conservation of Energy	3, 4, 5
Rotational Motion: Torque, Rotational Kinematics and Energy, Rotational Dynamics, and Conservation of Angular Momentum	3, 4, 5
Electrostatics: Electric Charge and Electric Force	1, 3, 5
DC Circuits: Resistors only	1, 5
Mechanical Waves and Sound	6

Physics 2 Principles	Big Ideas
Thermodynamics: Laws of Thermodynamics, Ideal Gases, and Kinetic Theory	1, 4, 5, 7
Fluid Statics and Dynamics	1, 3, 5
Electrostatics: Electric Force, Electric Field and Electric Potential	1, 2, 3, 4, 5
DC Circuits and RC Circuits (steady-state only)	1, 4, 5
Magnetism and Electromagnetic Induction	2, 3, 4
Geometric and Physical Optics	6
Quantum Physics, Atomic and Nuclear Physics	1, 3, 4, 5, 6, 7

The Laboratory Investigations

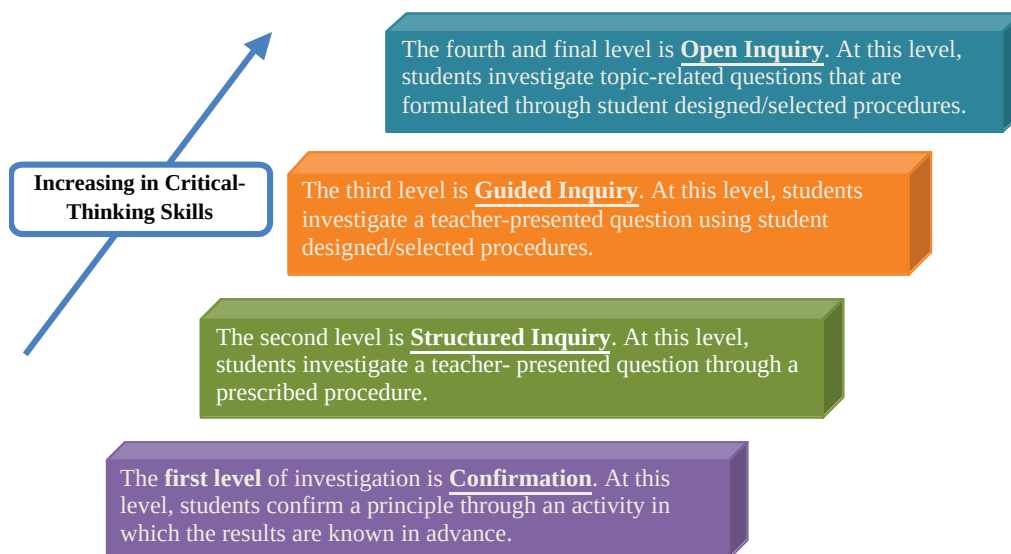
Inquiry-based laboratory experiences support the AP Physics 1 and AP Physics 2 courses and AP Course Audit Curricular Requirements by providing opportunities for students to engage in the seven science practices as they design plans for experiments, make predictions, collect and analyze data, apply mathematical routines, develop explanations, and communicate about their work.

The science practices that align to the concept outline of the curriculum framework capture important aspects of the work that scientists engage in, at the level of competence that college and university faculty expect students to possess at the end of an introductory college-level course. AP Physics teachers will see within the learning objectives how these practices are integrated with the course content, and they will be able to design laboratory investigations and instruction with these practices in mind.

Inquiry Instruction in the AP Science Classroom

The *AP Physics 1 and 2 Inquiry-Based Lab Investigations: A Teacher's Manual* supports recommendations by the National Science Foundation (NSF) that science teachers should include opportunities in their curricula for students to develop skills in communication, teamwork, critical thinking, and commitment to life-long learning (NSF 1996, NSF, 2012, AAPT 1992). An inquiry approach to laboratory work engages and inspires students to investigate meaningful questions about the physical world and align with the best practices described in *America's Lab Report*, a comprehensive synthesis of research about student learning in science laboratories from the National Research Council.

Scientific inquiry experiences in the AP classroom should be designed and implemented with increasing student involvement to help enhance inquiry learning and the development of critical-thinking and problem-solving skills and abilities. Adaptations of Herron’s approach (1971) and that of Rezba, Auldridge, and Rhea (1999) define inquiry instruction for investigations in four incremental ways:



Typically, the level of investigations in an AP classroom should focus primarily on the continuum between guided inquiry and open inquiry. However, depending on student familiarity with a topic, a given laboratory experience might incorporate a sequence involving all four levels or a subset of them. For instance, students might first carry out a simple confirmation investigation that also familiarizes them with equipment, and then proceed to a structured inquiry that probes more deeply into the topic and gives more practice with equipment. At that point, students would be presented with a question and asked to design/select their own procedure. A class discussion of results could then lead to questions that could be explored differently by different groups in open inquiry.

The idea of asking questions and inquiry is actually natural to students. However, in the classroom setting it may not seem natural to them as they may have developed more teacher-directed procedural habits and expectations in previous lab courses. As students experience more opportunities for more self-directed investigations with less teacher guidance, they will become more sophisticated in their reasoning and approach to inquiry. The teacher can promote inquiry habits in students throughout the course — during class and in the laboratory — by handing over more of the planning of experiments and manipulation of equipment over to students.

Time and Resources

Teachers are expected to devote a minimum of 25 percent of instructional time to laboratory work in each course. Additionally, students should be provided with an opportunity to engage in a minimum of seven inquiry-based investigations. The AP Physics 1 and AP Physics 2 courses emphasize depth of understanding over breadth of content. By limiting the scope of content in each of the courses, students have more time to engage in inquiry-based learning experiences that will develop conceptual understanding of content while building expertise in the science practices. Applying this instructional approach to laboratory investigations typically takes more time than simple verification/confirmation labs; however the reduced breadth of content will allow teachers to meet the AP Course Audit curricular requirements of 25 percent of course time that must be devoted laboratory work.

The labs in the *AP Physics 1 and 2 Inquiry-Based Lab Investigations: A Teacher's Manual* are intended to serve as models, **not as required activities**; teachers are encouraged to develop their own teacher-guided or student-directed inquiry-based labs that address the learning objectives in the curriculum framework. They should also consider supporting their physical laboratory work with interactive, online simulations, such as PhET simulations developed by the University of Colorado, Boulder.

References

- National Research Council. *National Science Education Standards*. Washington, DC: The National Academies Press, 1996.
- National Research Council. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2012.
- The Role of Labs in High School Physics*, American Association of Physics Teachers (AAPT), Position Paper, 1992. Accessed on July 27, 2013. <http://www.aapt.org/resources/policy/RoleOfLabs.cfm>
- Singer, Susan R., Margaret L. Hilton, and Heidi A. Schweingruber. *America's Lab Report: Investigations in High School Science*. Washington, DC: The National Academies Press, 2006.

Exam Information

Both the AP Physics 1 and the AP Physics 2 exams consist of two sections: multiple choice and free response. Each exam is 3 hours long and includes both a 90-minute multiple-choice section and a 90-minute free-response section. The multiple-choice section accounts for half of each student's exam grade, and the free-response section accounts for the other half. Both sections include questions aligned to the learning objectives and their associated science practices in order to assess students' ability to:

- Provide both qualitative and quantitative explanations, reasoning, or justification of physical phenomena, grounded in physics principles and theories
- Solve problems mathematically — including symbolically — but with less emphasis on only mathematical routines used for solutions
- Interpret and develop conceptual models
- Transfer knowledge and analytical skills developed during laboratory experiences to design and describe experiments and analyze data and draw conclusions based on evidence.

Section I in both AP Physics 1 and AP Physics 2 exams consists of 50 multiple-choice questions presented as discrete questions or questions in sets, that represent the knowledge and science practices outlined in the AP Physics 1 and AP Physics 2 learning objectives in the curriculum framework and which students should understand and be able to apply. These multiple-choice questions include two question types: single-select questions and multi-select questions having two correct answers (students need to select both correct answers to earn credit). Section I begins with 45 single-select questions, followed directly by five multi-select questions.

Section II contains three types of free-response questions and each student will have a total of 90 minutes to complete the entire section. The three free-response question types include:

- Experimental design — pertains to designing and describing an investigation, analysis of authentic lab data, and observations to identify patterns or explain phenomena
- Qualitative/quantitative translation — requires translating between quantitative and qualitative justification and reasoning
- Short-answer questions — one of which will require a paragraph-length coherent argument

Section	Timing	Scoring	Question Type	Number of Questions	
I: Multiple Choice	90 minutes	50% of exam score		Physics 1	Physics 2
			Single-select (discrete questions and questions in sets with one correct answer)	45	
			Multi-select (discrete questions with two correct answers)	5	
				Total – 50	

Section	Timing	Scoring	Question Type	Number of Questions	
II: Free Response	90 minutes	50% of exam score		Physics 1	Physics 2
			Experimental Design	1	1
			Qualitative/ Quantitative Translation	1	1
			Short Answer	3	2
				Total – 5	Total – 4

The sample exam questions in this course and exam description represent the kinds of questions that are included on the AP Physics 1 and AP Physics 2 exams. The concepts, content, application of science practices, and the level of difficulty in these sample questions are comparable to what students will encounter on an actual AP Exam. Each sample multiple-choice and free-response question is followed by a text box that shows each question's alignment with the learning objectives and science practices provided in the *AP Physics 1: Algebra-Based* and *AP Physics 2: Algebra-Based Curriculum Framework*.

Beginning with the May 2015 administration of the AP Physics 1 and AP Physics 2 exams, multiple-choice questions will contain four answer options, rather than five. This change will save students valuable time without altering the rigor of the exams in any way. A student's total score on the multiple-choice section is based on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Student Work for Free-Response Sections – Terms Defined

In scoring the free-response sections, credit for the answers depends on the quality of the solutions and the explanations given; partial solutions may receive partial credit, so students are advised to *show all their work*. Correct answers without supporting work may lose credit. This is especially true when students

are asked specifically to justify their answers, in which case the AP Exam Readers are looking for some verbal or mathematical analysis that shows how the students arrived at their answers. Also, all final numerical answers should include appropriate units.

On the AP Physics 1 and AP Physics 2 exams, the words “describe,” “explain,” “justify,” “calculate,” “derive,” “what is,” “determine,” “sketch,” “plot,” “draw,” “label,” “design,” and “outline” have precise meanings.

Students should pay careful attention to these words in order to obtain maximum credit and should avoid including irrelevant or extraneous material in their answers.

- Students will be asked both to “**describe**” and “**explain**” natural phenomena. Both terms require the ability to demonstrate an understanding of physics principles by providing an accurate and coherent description or explanation. Students will also be asked to “**justify**” a previously given answer. A justification is an argument, supported by evidence. Evidence may consist of statements of physical principles, equations, calculations, data, graphs, and diagrams as appropriate. The argument, or equations used to support justifications and explanations, may in some cases refer to fundamental ideas or relations in physics, such as Newton’s laws, conservation of energy, or Bernoulli’s equation. In other cases, the justification or explanation may take the form of analyzing the behavior of an equation for large or small values of a variable in the equation.
- “**Calculate**” means that a student is expected to show work leading to a final answer, which may be algebraic but more often is numerical. “**Derive**” is more specific and indicates that the students need to begin their solutions with one or more fundamental equations, such as those given on the AP Physics 1 or AP Physics 2 Exam equation sheet. The final answer, usually algebraic, is then obtained through the appropriate use of mathematics. “**What is**” and “**determine**” are indicators that work need not necessarily be explicitly shown to obtain full credit. Showing work leading to answers is a good idea, as it may earn a student partial credit in the case of an incorrect answer. Strict rules regarding significant digits are usually not applied to the scoring of numerical answers. However, in some cases, answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer.
- The words “**sketch**” and “**plot**” relate to student-produced graphs. “Sketch” means to draw a graph that illustrates key trends in a particular relationship, such as slope, curvature, intercept(s), or asymptote(s). Numerical scaling or specific data points are not required

in a sketch. “Plot” means to draw the data points given in the problem on the grid provided, either using the given scale or indicating the scale and units when none are provided.

- Exam questions that require the drawing of free-body or force diagrams will direct the students to “**draw** and **label** the forces (not components) that act on the [object],” where [object] is replaced by a reference specific to the question, such as “the car when it reaches the top of the hill.” Any components that are included in the diagram will be scored in the same way as incorrect or extraneous forces. In addition, in any subsequent part asking for a solution that would typically make use of the diagram, the following will be included: “If you need to draw anything other than what you have shown in part [x] to assist in your solution, use the space below. Do NOT add anything to the figure in part [x].” This will give students the opportunity to construct a working diagram showing any components that are appropriate to the solution of the problem. This second diagram will not be scored.
- Some questions will require students to “design” an experiment or “outline” a procedure that investigates a specific phenomenon or would answer a guiding question. Students are expected to provide an orderly sequence of statements that specifies the necessary steps in the investigation needed to reasonably answer the question or investigate the phenomenon.

Calculators and Equation Tables

Students will be allowed to use a calculator on the entire AP Physics 1 and AP Physics 2 exams — including both the multiple-choice and free-response sections. Scientific or graphing calculators may be used, provided that they don’t have any unapproved features or capabilities (a list of approved graphing calculators is available at <https://apstudent.collegeboard.org/apcourse/ap-calculus-ab/calculator-policy>). Calculator memories do not need to be cleared before or after the exam. Since graphing calculators can be used to store data, including text, proctors should monitor that students are using their calculators appropriately. Communication between calculators is prohibited during the exam administration. Attempts by students to use the calculator to remove exam questions and/or answers from the room may result in the invalidation of AP Exam scores. The policy regarding the use of calculators on the AP Physics 1 and AP Physics 2 exams was developed to address the rapid expansion of the capabilities of calculators, which include not only programming and graphing functions but also the availability of stored equations and other data. Students should be allowed to use the calculators to which they are accustomed. However, students should be encouraged to develop their skills in estimating answers and orders of magnitude quickly and in recognizing answers that are physically unreasonable or unlikely.

Tables containing equations commonly used in physics will be provided for students to use during the entire AP Physics 1 and AP Physics 2 exams. In general, the equations for each year's exam are printed and distributed with the course and exam description at least a year in advance so that students can become accustomed to using them throughout the year. However, because the equation tables will be provided with the exam, students will NOT be allowed to bring their own copies to the exam room. The latest version of the equations and formulas list is included in Appendix B to this course and exam description. One of the purposes of providing the tables of commonly employed equations for use with the exam is to address the issue of equity for those students who do not have access to equations stored in their calculators. The availability of these equations to all students means that in the scoring of the exam, little or no credit will be awarded for simply writing down equations or for answers unsupported by explanations or logical development.

In general, the purpose of allowing calculators and equation sheets to be used in both sections of the exam is to place greater emphasis on the understanding and application of fundamental physical principles and concepts. For solving problems and writing essays, a sophisticated scientific or graphing calculator, or the availability of stored equations, is no substitute for a thorough grasp of the physics involved.

Time Management

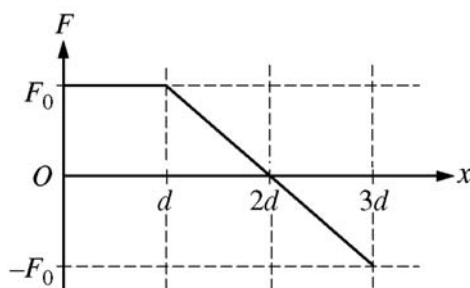
Students need to learn to manage their time to allow them to complete all parts of the exam. Time left is announced periodically by proctors, but students are not forced to move to the next question; thus, if they do not properly budget their time, they may have insufficient time to complete all the multiple-choice questions in Section I and all of the free-response questions in Section II. Students often benefit from taking a practice exam under timed conditions prior to the actual administration.

Sample Questions for the AP Physics 1 Exam

Multiple-Choice Questions

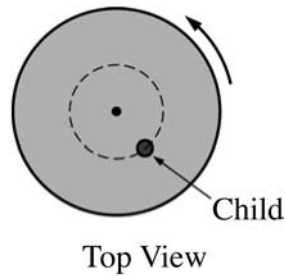
Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.



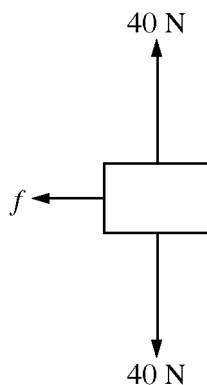
1. An object is moving in the positive x -direction while a net force directed along the x -axis is exerted on the object. The figure above shows the force as a function of position. What is the net work done on the object over the distance shown?
- (A) $F_0 d$
 (B) $3F_0 d/2$
 (C) $2F_0 d$
 (D) $4F_0 d$

Essential Knowledge	5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.
Learning Objectives	5.B.5.3: The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.



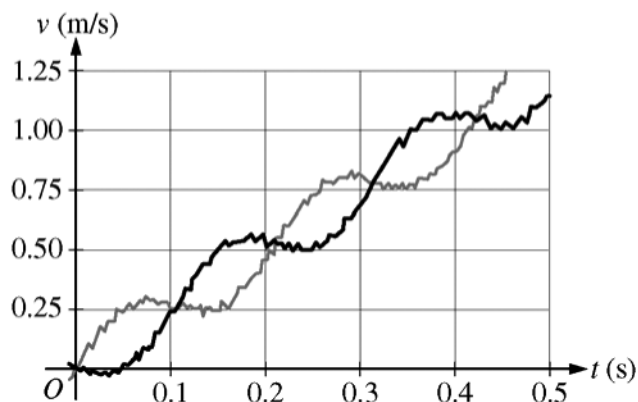
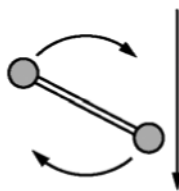
2. The diagram above shows a top view of a child of mass M on a circular platform of mass $2M$ that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following describes an action by the child that will increase the angular speed of the platform-child system and gives the correct reason why?
- (A) The child moves toward the center of the platform, increasing the total angular momentum of the system.
 - (B) The child moves toward the center of the platform, decreasing the rotational inertia of the system.
 - (C) The child moves away from the center of the platform, increasing the total angular momentum of the system.
 - (D) The child moves away from the center of the platform, decreasing the rotational inertia of the system.

Essential Knowledge	5.E.1: If the net external torque exerted on the system is zero, the angular momentum of the system does not change.
Learning Objectives	5.E.1.1: The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.



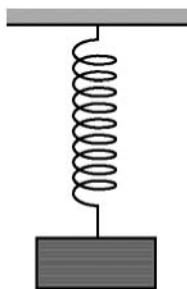
3. The figure above shows the forces exerted on a block that is sliding on a horizontal surface: the gravitational force of 40 N, the 40 N normal force exerted by the surface, and a frictional force exerted to the left. The coefficient of friction between the block and the surface is 0.20. The acceleration of the block is most nearly
- (A) 1.0 m/s² to the right
 - (B) 1.0 m/s² to the left
 - (C) 2.0 m/s² to the right
 - (D) 2.0 m/s² to the left

Essential Knowledge	2.B.1: A gravitational field g at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field. 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
Learning Objectives	2.B.1.1: The student is able to apply $\vec{F} = m\vec{g}$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 3.B.1.3: The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



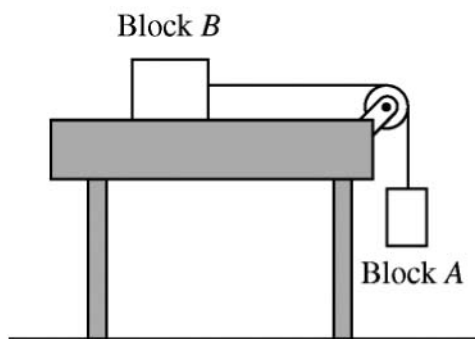
4. A student on another planet has two identical spheres, each of mass 0.6 kg, attached to the ends of a rod of negligible mass. The student gives the assembly a rotation in the vertical plane and then releases it so it falls, as shown in the top figure above. Sensors record the vertical velocity of the two spheres, and the data is shown in the graph of velocity v as a function of time t . Another student wants to calculate the assembly's angular speed and the change in the linear momentum of the center of mass of the assembly between 0 s and 0.3 s. Which of these quantities can be determined using the graph?
- (A) Angular speed only
- (B) Change in linear momentum only
- (C) Angular speed and change in linear momentum
- (D) Neither of these quantities can be determined using the graph.

Essential Knowledge	3.F.2: The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis. 4.B.1: The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.
Learning Objectives	3.F.2.2: The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis. 4.B.1.2: The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.
Science Practices	5.1: The student can <i>analyze data</i> to identify patterns or relationships.



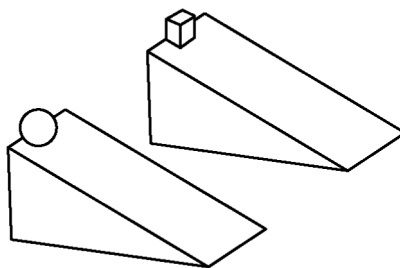
5. A block of known mass hanging from an ideal spring of known spring constant is oscillating vertically. A motion detector records the position, velocity, and acceleration of the block as a function of time. Which of the following indicates the measured quantities that are sufficient to determine whether the net force exerted on the block equals the vector sum of the individual forces?
- (A) Acceleration only
 - (B) Acceleration and position only
 - (C) Acceleration and velocity only
 - (D) Acceleration, position, and velocity

Essential Knowledge	3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum and mass-spring oscillator.
Learning Objectives	3.B.1.2: The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. 3.B.3.3: The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.
Science Practices	5.1: The student can <i>analyze data</i> to identify patterns or relationships.



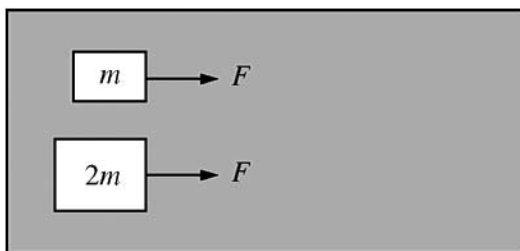
6. Block A hangs from a light string that passes over a light pulley and is attached to block B, which is on a level horizontal frictionless table, as shown above. Students are to determine the mass of block B from the motion of the two-block system after it is released from rest. They plan to measure the time block A takes to reach the floor. The students must also take which of the following measurements to determine the mass of block B?
- (A) Only the mass of block A
 - (B) Only the distance block A falls to reach the floor
 - (C) Only the mass of block A and the distance block A falls to reach the floor
 - (D) The mass of block A, the distance block A falls to reach the floor, and the radius of the pulley

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
Learning Objectives	3.A.1.2: The student is able to design an experimental investigation of the motion of an object. 4.A.2.1: The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.
Science Practices	4.2: The student can <i>design a plan</i> for collecting data to answer a particular scientific question. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

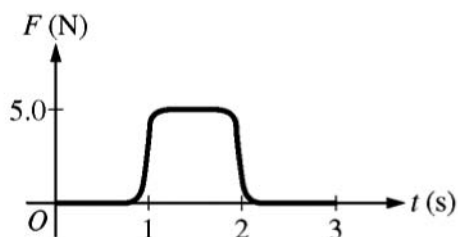


7. Two objects are released from rest at the top of ramps with the same dimensions, as shown in the figure above. The sphere rolls down one ramp without slipping. The small block slides down the other ramp without friction. Which object reaches the bottom of its ramp first, and why?
- (A) The sphere, because it gains rotational kinetic energy, but the block does not
 - (B) The sphere, because it gains mechanical energy due to the torque exerted on it, but the block does not
 - (C) The block, because it does not lose mechanical energy due to friction, but the sphere does
 - (D) The block, because it does not gain rotational kinetic energy, but the sphere does

Essential Knowledge	5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system. 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.
Learning Objectives	5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system using information from representations of that system. 5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.



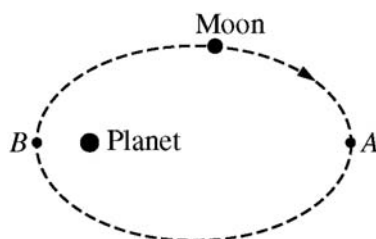
Top View



8. Two blocks, of mass m and $2m$, are initially at rest on a horizontal frictionless surface. A force F is exerted individually on each block, as shown above. The graph shows how F varies with time t . Which block has the greatest average power provided to it between $t = 0$ s and $t = 3$ s?
- (A) The block of mass m
 - (B) The block of mass $2m$
 - (C) Both blocks have the same power provided to them.
 - (D) It cannot be determined without knowing the ratio of the maximum force to the mass m .

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted. 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 3.E.1.4: The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object. 5.B.5.3: The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance. 5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

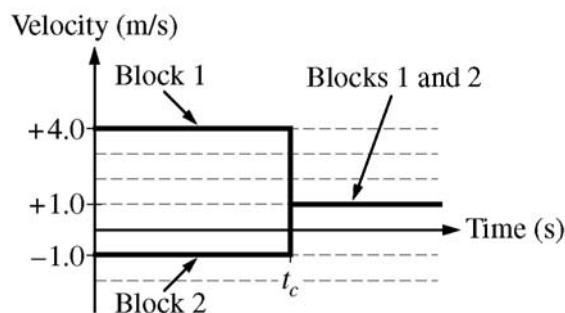
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.



9. A moon is in an elliptical orbit about a planet as shown above. At point A the moon has speed u_A and is at distance R_A from the planet. At point B the moon has speed u_B . Which of the following explains a correct method for determining the distance of the moon from the planet at point B in terms of the given quantities?
- (A) Conservation of angular momentum, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon
 - (B) Conservation of angular momentum, because the gravitational force exerted on the moon is always directed toward the planet
 - (C) Conservation of energy, because the gravitational force exerted on the moon is always directed toward the planet
 - (D) Conservation of energy, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon

Essential Knowledge	5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system. 5.E.1: If the net external torque exerted on the system is zero, the angular momentum of the system does not change.
Learning Objectives	5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). 5.E.1.1: The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Questions 10–12 refer to the following material.



Block 1 of mass m_1 and block 2 of mass m_2 are sliding along the same line on a horizontal frictionless surface when they collide at time t_c . The graph above shows the velocities of the blocks as a function of time.

10. Which block has the greater mass, and what information indicates this?
- (A) Block 1, because it had a greater speed before the collision.
 - (B) Block 1, because the velocity after the collision is in the same direction as its velocity before the collision.
 - (C) Block 2, because it had a smaller speed before the collision.
 - (D) Block 2, because the final velocity is closer to the initial velocity of block 2 than it is to the initial velocity of block 1.

Essential Knowledge	4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time. 5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
Learning Objectives	4.A.2.3: The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. 5.D.2.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

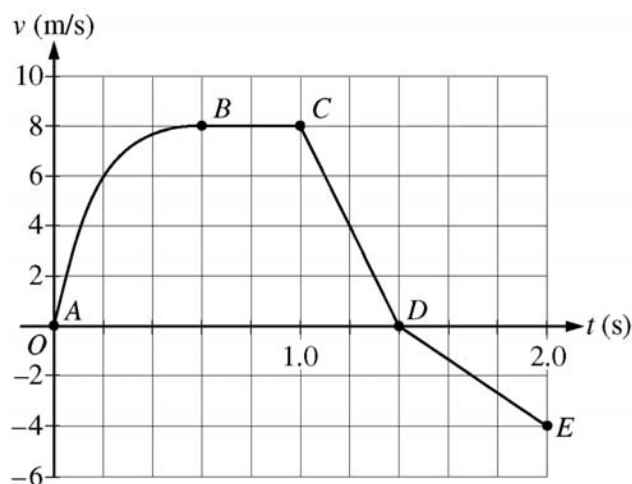
11. How does the kinetic energy of the two-block system after the collision compare with its kinetic energy before the collision, and why?
- (A) It is less, because the blocks have the same velocity after the collision, so some of their kinetic energy was transformed into internal energy.
 - (B) It is less, because the blocks have velocities in opposite directions before the collision, so some of their kinetic energy cancels.
 - (C) It is the same, because the collision was instantaneous, so the effect of external forces during the collision is negligible.
 - (D) It is the same, because the blocks have the same velocity after the collision, and there is no friction acting on them.

Essential Knowledge	5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
Learning Objectives	5.D.2.3: The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

12. Which of the following is true of the motion of the center of mass of the two-block system during the time shown?
- (A) The center of mass does not move because the blocks are moving in opposite directions before the collision.
 - (B) The center of mass moves at a constant velocity of $+1.0$ m/s because there is no friction acting on the system.
 - (C) The center-of-mass velocity starts out greater than $+1.0$ m/s but decreases to $+1.0$ m/s during the collision because the collision is inelastic.
 - (D) The center-of-mass velocity increases as the blocks get closer together, and then becomes constant after the collision.

Essential Knowledge	4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
Learning Objectives	4.A.2.3: The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

Questions 13–15 refer to the following information.



A cart is constrained to move along a straight line. A varying net force along the direction of motion is exerted on the cart. The cart's velocity v as a function of time t is shown in the graph above. The five labeled points divide the graph into four sections.

13. Which of the following correctly ranks the magnitude of the average acceleration of the cart during the four sections of the graph?
- (A) $a_{CD} > a_{AB} > a_{BC} > a_{DE}$
- (B) $a_{BC} > a_{AB} > a_{CD} > a_{DE}$
- (C) $a_{AB} > a_{BC} > a_{DE} > a_{CD}$
- (D) $a_{CD} > a_{AB} > a_{DE} > a_{BC}$

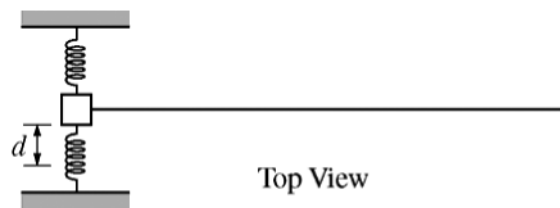
Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 3.A.1.3: The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.
Science Practices	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

14. For which segment does the cart move the greatest distance?
- (A) *AB*
- (B) *BC*
- (C) *CD*
- (D) *DE*

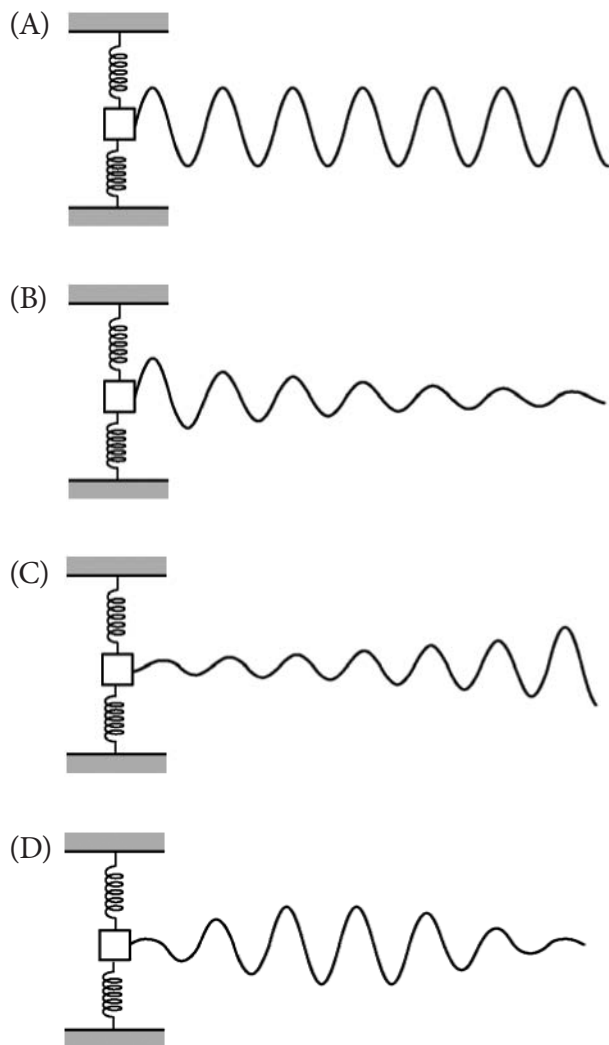
Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
Science Practices	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

15. During some part of the motion, the work done on the cart is negative. What feature of the motion indicates this?
- (A) The speed is increasing.
- (B) The speed is decreasing.
- (C) The acceleration is positive.
- (D) The acceleration is negative.

Essential Knowledge	3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted. 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.
Learning Objectives	3.E.1.3: The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged. 5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



16. The figure above shows a block on a horizontal surface attached to two springs whose other ends are fixed to walls. A light string attached to one side of the block initially lies straight across the surface, as shown. The other end of the string is free to move. There is significant friction between the block and the surface but negligible friction between the string and the surface. The block is displaced a distance d and released from rest. Which of the following best represents the shape of the string a short time later?

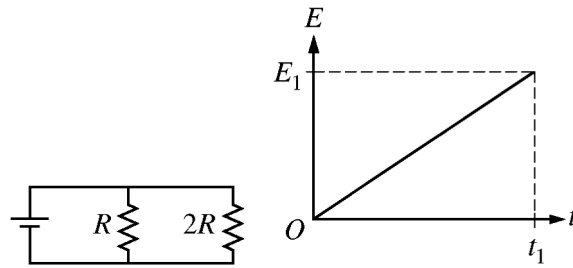


Essential Knowledge	3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum and mass-spring oscillator. 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work. 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.
Learning Objectives	3.B.3.1: The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. 4.C.2.1: The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. 6.A.3.1: The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

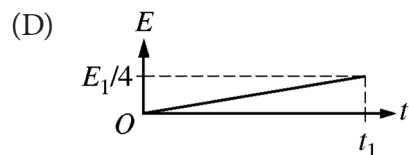
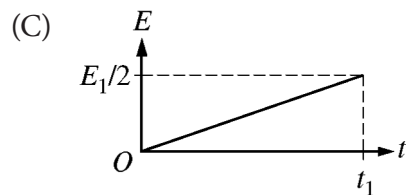
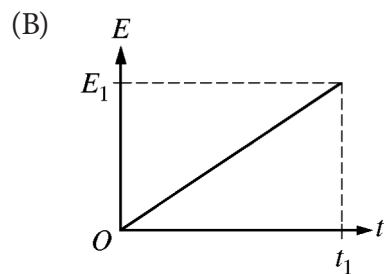
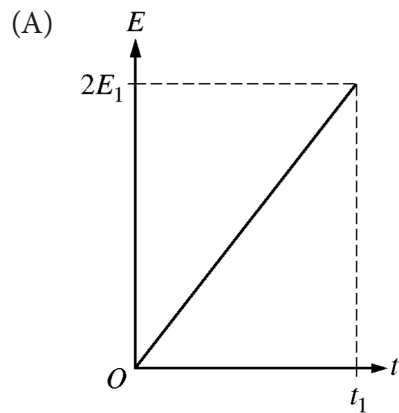
17. Two massive, positively charged particles are initially held a fixed distance apart. When they are moved farther apart, the magnitude of their mutual gravitational force changes by a factor of n . Which of the following indicates the factor by which the magnitude of their mutual electrostatic force changes?

- (A) $1/n^2$
- (B) $1/n$
- (C) n
- (D) n^2

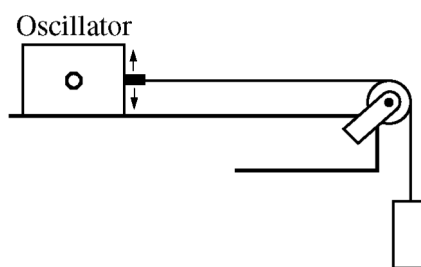
Essential Knowledge	3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
Learning Objectives	3.C.2.1: The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges (interactions between collections of electric point charges are not covered in Physics 1 and instead are restricted to Physics 2). 3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



18. The circuit shown above contains two resistors of resistance R and $2R$. The graph shows the total energy E dissipated by the smaller resistance as a function of time. Which of the following shows the corresponding graph for the larger resistance?

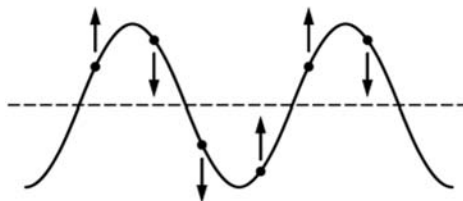


Essential Knowledge	5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]
Learning Objectives	5.B.9.1: The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule). 5.B.9.3: The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch.
Science Practices	1.1: The student can <i>create representations and models</i> of natural or man-made phenomena and systems in the domain. 1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



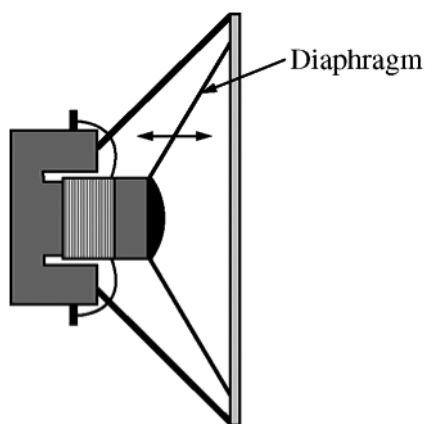
19. A student connects one end of a string with negligible mass to an oscillator. The other end of the string is passed over a pulley and attached to a suspended weight, as shown above. The student finds that a standing wave with one antinode is formed on the string when the frequency of the oscillator is f_0 . The student then moves the oscillator to shorten the horizontal segment of string to half its original length. At what frequency will a standing wave with one antinode now be formed on the string?
- (A) $f_0/2$
 (B) f_0
 (C) $2f_0$
 (D) There is no frequency at which a standing wave will be formed.

Essential Knowledge	6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.
Learning Objectives	6.D.4.2: The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.
Science Practices	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.



20. The figure above shows a portion of a periodic wave on a string at a particular moment in time. The vertical arrows indicate the direction of the velocity of some points on the string. Is the wave moving to the right or to the left?
- (A) To the right
 - (B) To the left
 - (C) Neither direction; the wave is a standing wave, so it is not moving.
 - (D) Either direction; the figure is consistent with wave motion to the right or to the left.

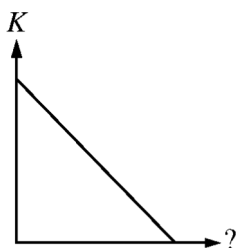
Essential Knowledge	6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.
Learning Objectives	6.A.1.2: The student is able to describe representations of transverse and longitudinal waves.
Science Practices	1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain.



21. A radio speaker produces sound when a membrane called a diaphragm vibrates, as shown above. A person turns up the volume on the radio. Which of the following aspects of the motion of a point on the diaphragm must increase?
- (A) The maximum displacement only
 - (B) The average speed only
 - (C) Both the maximum displacement and the average speed
 - (D) Neither the maximum displacement nor the average speed

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 6.A.2.1: The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.
Science Practices	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Directions: For each of questions 22–25 below, two of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.



22. A block is given a short push and then slides with constant friction across a horizontal floor. The graph above shows the kinetic energy of the block after the push ends as a function of an unidentified quantity. The quantity could be which of the following? Select two answers.
- (A) Time elapsed since the push
 - (B) Distance traveled by the block
 - (C) Speed of the block
 - (D) Magnitude of the net work done on the block

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted.

Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 3.E.1.1: The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.
Science Practices	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

23. A musician stands outside in a field and plucks a string on an acoustic guitar. Standing waves will most likely occur in which of the following media? Select two answers.

- (A) The guitar string
- (B) The air inside the guitar
- (C) The air surrounding the guitar
- (D) The ground beneath the musician

Essential Knowledge	6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.
Learning Objectives	6.D.3.2: The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. 6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.
Science Practices	1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

24. A 0.2 kg rock is dropped into a lake from a few meters above the surface of the water. The rock reaches terminal velocity in the lake after 5 s in the water. During the final 3 s of its descent to the lake bottom, the rock moves at a constant speed of 4 m/s. Which of the following can be determined from the information given? Select two answers.

- (A) The speed of the rock as it enters the lake
- (B) The distance the rock travels in the first 5 s of its descent in the water
- (C) The acceleration of the rock 2 s before it reaches the lake bottom
- (D) The change in potential energy of the rock-Earth-water system during the final 3 s of the rock's descent

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 4.C.1: The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 4.C.1.2: The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.
Science Practices	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

25. In an experiment, three microscopic latex spheres are sprayed into a chamber and become charged with $+3e$, $+5e$, and $-3e$, respectively. Later, all three spheres collide simultaneously and then separate. Which of the following are possible values for the final charges on the spheres? Select two answers.

	<u>X</u>	<u>Y</u>	<u>Z</u>
(A)	$+4e$	$-4e$	$+5e$
(B)	$-4e$	$+4.5e$	$+4.5e$
(C)	$+5e$	$-8e$	$+7e$
(D)	$+6e$	$+6e$	$-7e$

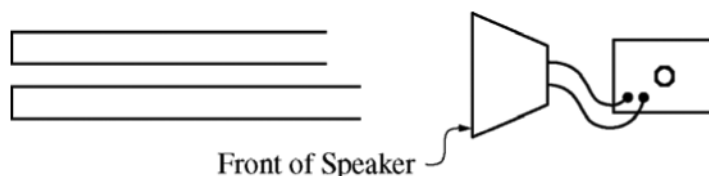
Essential Knowledge	1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system. 1.B.3: The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
Learning Objectives	1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. 1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Answers to Multiple-Choice Questions

1. A	14. A
2. B	15. B
3. D	16. C
4. C	17. C
5. B	18. C
6. C	19. C
7. D	20. B
8. A	21. C
9. B	22. B, D
10. D	23. A, B
11. A	24. C, D
12. B	25. A, D
13. D	

Free-Response Questions

Directions: Question 1 is a short free-response question that requires about 12 minutes to answer and is worth 7 points. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



- The figure above shows two tubes that are identical except for their slightly different lengths. Both tubes have one open end and one closed end. A speaker connected to a variable frequency generator is placed in front of the tubes, as shown. The speaker is set to produce a note of very low frequency and then turned on. The frequency is then slowly increased to produce resonances in the tubes. Students observe that at first only one of the tubes resonates at a time. Later, as the frequency gets very high, there are times when both tubes resonate.

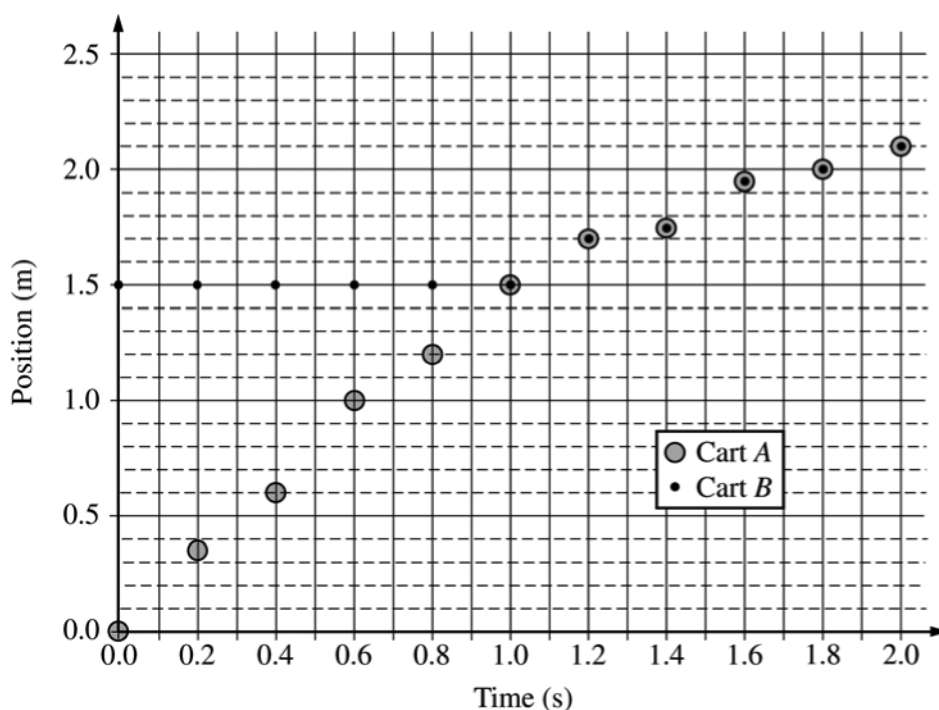
In a clear, coherent, paragraph-length answer, explain why there are some high frequencies, but no low frequencies, at which both tubes resonate. You may include diagrams and/or equations as part of your explanation.

Essential Knowledge	6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.
	6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.
Learning Objectives	6.D.3.2: The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.
	6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.
	6.D.4.1: The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.
Science Practices	1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
	6.1: The student can justify claims with evidence.
	6.4: The student can make claims and predictions about natural phenomena based on scientific theories and models.



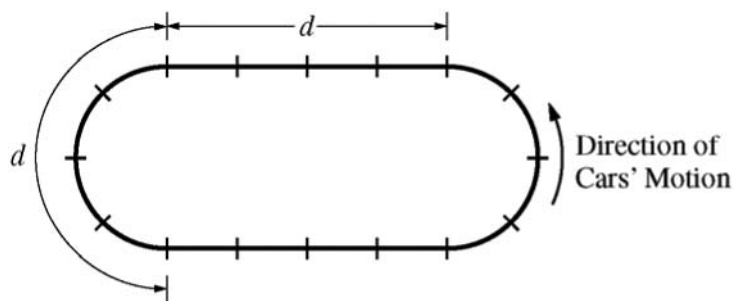
2. A group of students has two carts, A and B, with wheels that turn with negligible friction. The carts can travel along a straight horizontal track. Cart A has known mass m_A . The students are asked to use a one-dimensional collision between the carts to determine the mass of cart B. Before the collision, cart A travels to the right and cart B is initially at rest, as shown above. After the collision, the carts stick together.
- Describe an experimental procedure to determine the velocities of the carts before and after a collision, including all the additional equipment you would need. You may include a labeled diagram of your setup to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that another student could carry out your procedure.
 - There will be sources of error in the measurements taken in the experiment, both before and after the collision. For your experimental procedure, will the uncertainty in the calculated value of the mass of cart B be affected more by the error in the measurements taken before the collision or by those taken after the collision, or will it be equally affected by both sets of measurements? Justify your answer.

A group of students took measurements for one collision. A graph of the students' data is shown below.



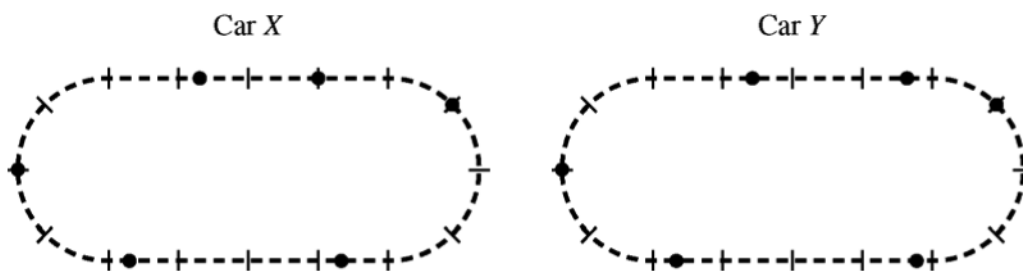
- (c) Given $m_A = 0.50$ kg, use the graph to calculate the mass of cart B . Explicitly indicate the principles used in your calculations.
- (d) The students are now asked to consider the kinetic energy changes in an inelastic collision, specifically whether the initial values of one of the physical quantities affect the fraction of mechanical energy dissipated in the collision. How could you modify the experiment to investigate this question? Be sure to explicitly describe the calculations you would make, specifying all equations you would use (but do not actually do any algebra or arithmetic).

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
	5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
Learning Objectives	3.A.1.2: The student is able to design an experimental investigation of the motion of an object.
	5.D.1.4: The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.
	5.D.2.2: The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
Science Practices	4.2: The student can <i>design a plan</i> for collecting data to answer a particular scientific question.
	5.1: The student can <i>analyze data</i> to identify patterns or relationships.
	5.3: The student can <i>evaluate the evidence provided by data sets</i> in relation to a particular scientific question.



3. The figure above represents a racetrack with semicircular sections connected by straight sections. Each section has length d , and markers along the track are spaced $d/4$ apart. Two people drive cars counterclockwise around the track, as shown. Car X goes around the curves at constant speed v_c , increases speed at constant acceleration for half of each straight section to reach a maximum speed of $2v_c$, then brakes at constant acceleration for the other half of each straight section to return to speed v_c . Car Y also goes around the curves at constant speed v_c , increases speed at constant acceleration for one-fourth of each straight section to reach the same maximum speed $2v_c$, stays at that speed for half of each straight section, then brakes at constant acceleration for the remaining fourth of each straight section to return to speed v_c .

- (a) On the figures below, draw an arrow showing the direction of the net force on each of the cars at the positions noted by the dots. If the net force is zero at any position, label the dot with 0.



(b)

- Indicate which car, if either, completes one trip around the track in less time, and justify your answer qualitatively without using equations.
- Justify your answer about which car, if either, completes one trip around the track in less time quantitatively with appropriate equations.

- (c) Explain how your equations in part (b) ii reexpress your reasoning in part (b) i. Do not simply refer to any final results of your calculations, but instead indicate how terms in your equations correspond to concepts in your qualitative explanation.

Essential Knowledge	3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	3.A.2: Forces are described by vectors.
Learning Objectives	3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
	3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
Science Practices	1.1: The student can <i>create representations and models</i> of natural or man-made phenomena and systems in the domain.
	1.5: The student can <i>reexpress key elements of natural phenomena across multiple representations</i> in the domain.
	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

Scoring Guidelines

Scoring Guidelines for Free-Response Question 1 (7 points)

Explanations can include figures to support or clarify the meaning of prose, but figures alone are not sufficient.

For explaining the condition for resonance in a tube closed at one end 2 points

For comparing wavelengths at low frequency to the tube lengths 1 point

For linking the above two ideas (conditions of resonance and comparing wavelengths at low frequency) to explain why only one resonance occurs at a time 1 point

For indicating that as frequency goes up, wavelength goes down 1 point

For indicating how smaller wavelengths relate to differences in tube length, explaining how both tubes can now meet boundary conditions 2 points

Example:

In order to resonate, the length of a tube must be an odd multiple of a quarter wavelength of the sound, as shown below.



For resonance at low frequencies, the wavelength of the sound is of the order of the length of the tubes. So the match can occur for only one tube at a time — the difference in tube lengths is much smaller than a half wavelength. As the frequency increases, the wavelength decreases and many more wavelengths fit inside a tube. When half the wavelength becomes of the order of the difference in tube lengths, the tubes can contain an odd multiple of quarter wavelengths for the same wavelength at the same time — for instance, one tube might contain 17 quarter wavelengths while the other contains 19 quarter wavelengths.

Scoring Guidelines for Free-Response Question 2 (12 points)

(a) (3 points)

For a reasonable setup that would allow useful measurements	1 point
For indicating all the measurements needed to determine the velocities	1 point
For having no obviously extraneous equipment or measurements	1 point

Examples:

- Use tape to mark off two distances on the track — one for cart *A* before the collision and one for the combined carts after the collision. Push cart *A* to give it an initial speed. Use a stopwatch to measure the time it takes for the cart(s) to cross the marked distances. The speeds are the distances divided by the times.
- Place a motion detector at the left end of the track. Push cart *A* to give it an initial speed. Record position as a function of time, first for cart *A* and then for the combined carts *A* and *B*.

(b) (2 points)

For indicating a reasonable assumption about the relative size of the measurement errors before and after the collision	1 point
For correctly using the assumption in comparing the effect on the calculated value of the mass of cart <i>B</i>	1 point

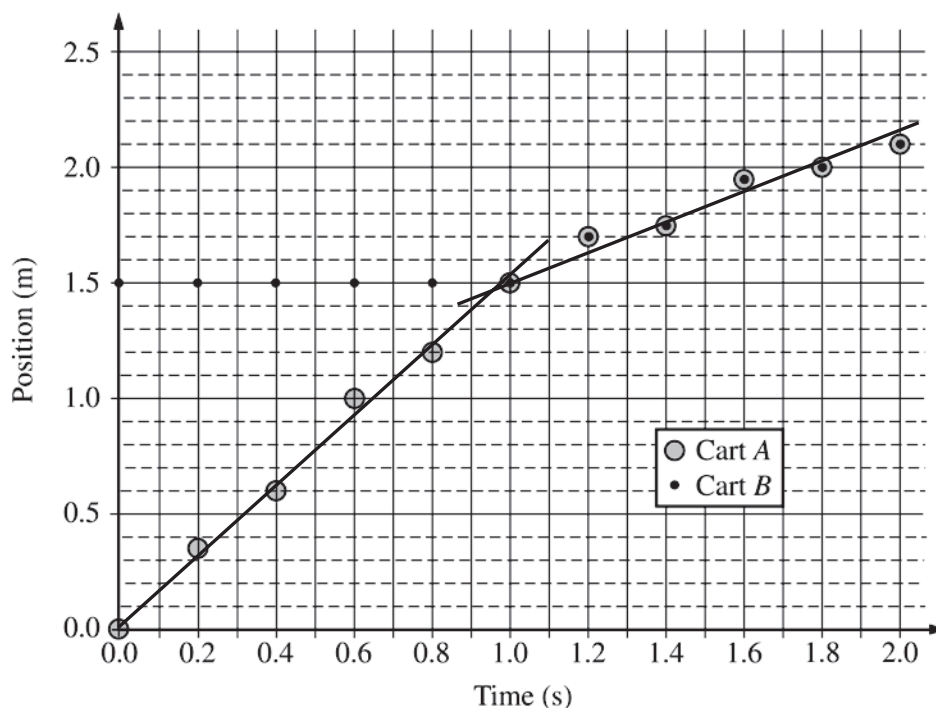
Example:

If the measurement errors are of the same magnitude, they will have a greater effect after the collision. The speed of the combined carts will be less than the initial speed of cart *A*, so errors of the same magnitude will be a greater percentage of the actual value after the collision. So the values after the collision will have a greater effect on the value of the mass of cart *B*.

A response could also argue any of the following:

- Measurement error could be greater before the collision (it could be harder to measure with the same accuracy at the greater speed). So percent error could be the same or greater.
- Measurement error could be greater before the collision (it could be harder to measure with the same accuracy at the greater speed). So the magnitude of the reported uncertainty could be the same.
- Measurement error could be the same before and after the collision if the same motion detector is used throughout.

(c) (4 points)



For providing sufficient description of the principles used in the calculation (in either a single explanation or dispersed throughout the calculations) 1 point

Conservation of momentum can be used to determine the mass of cart B:

$$m_A v_i = (m_A + m_B) v_f$$

For correctly recognizing the two regions on the graph corresponding to before and after the collision 1 point

For using data from the graph to attempt calculation of speed from slope 1 point

For indicating use of the slope of one or two drawn lines to determine one or more speeds (This point cannot be earned if calculations use data points not on the line[s].) 1 point

The speed v_i before the collision is the slope of the best-fit line for the data from 0 to 1 s.

The speed v_f after the collision is the slope of the best-fit line for the data from 1 s to 2 s.

Using the example lines drawn above:

$$v_i = \frac{(1.4 - 0) \text{ m}}{(0.9 - 0) \text{ s}} = \frac{14}{9} \frac{\text{m}}{\text{s}}$$

$$v_f = \frac{(2.1 - 1.5) \text{ m}}{(1.9 - 1.0) \text{ s}} = \frac{0.6 \text{ m}}{0.9 \text{ s}} = \frac{2}{3} \frac{\text{m}}{\text{s}}$$

Applying conservation of momentum:

$$(0.5 \text{ kg}) \left(\frac{14}{9} \frac{\text{m}}{\text{s}} \right) = (0.5 \text{ kg} + m_B) \left(\frac{2}{3} \frac{\text{m}}{\text{s}} \right)$$

$$(0.5 \text{ kg}) \left(\frac{14}{9} \right) \left(\frac{3}{2} \right) = (0.5 \text{ kg} + m_B)$$

$$(0.5 \text{ kg}) \left(\frac{7}{3} \right) = (0.5 \text{ kg} + m_B)$$

$$m_B = (0.5 \text{ kg}) \left(\frac{7}{3} - 1 \right) = (0.5 \text{ kg}) \left(\frac{4}{3} \right) = \frac{2}{3} \text{ kg}$$

(d) (3 points)

For an answer consistent with previous responses that indicates a modification of the procedure to accomplish varying the initial speed of cart A or one of the cart masses OR that indicates that the previously described procedure would provide appropriate data, so it does not need modification 1 point

For indicating that the data can be used to calculate the kinetic energy K before and after the collision 1 point

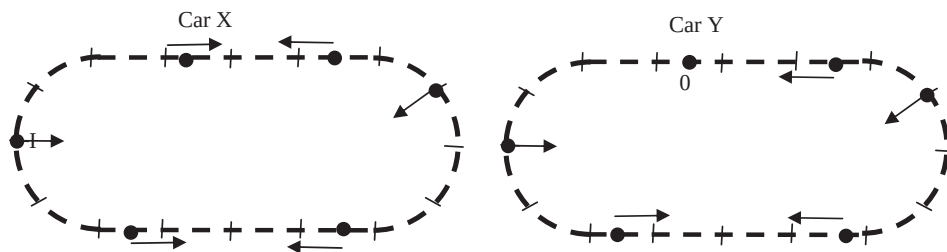
For indicating that the fraction of K lost in the various collisions should be compared 1 point

Example:

You could vary the initial speed of cart A. From the data, calculate values of kinetic energy before and after the collision using $K = (1/2)mv^2$. Then analyze $((K_i - K_f)/K_i)$ to see if the changes in initial speed give different values.

Scoring Guidelines for Free-Response Question 3 (12 points)

(a) (3 points)



For correct directions of the net forces at all the locations on the semicircular sections (i.e., all directed generally toward the center of the circle) 1 point

For correct directions of the net forces at all the locations on the bottom straightaways (i.e., directed toward the center of the segment) 1 point

For correct directions of the net forces at all locations on the top straightaway (i.e., both rightmost arrows directed toward the left, the left one for car X directed toward the right, and the left one for car Y equal to zero) 1 point

(b) (7 points total)

i) (2 points)

For realizing that the difference in time is only on the straightaways 1 point

For correct reasoning leading to Car Y taking a shorter time on the straightaways 1 point

Example:

Car X takes longer to accelerate and does not spend any time traveling at top speed. Car Y accelerates over a shorter time and spends time going at top speed. So car Y must cover the straightaways in a shorter time. Curves take the same time, so car Y must overall take a shorter time.

ii) (5 points)

The time to travel each curve is d/v_c . Answers can be expressed in terms of d/v_c or $t_c = d/v_c$ or some other defined unit of time. The calculations below will use $t_c = d/v_c$.

For stating that the time to travel each curve is d/v_c 1 point

For correct kinematics expressions that allow determination of the time it takes for one segment of acceleration on the straightaways 1 point

Example: $D = v_c t_1 + \frac{1}{2} a t_1^2$, $a = (2v_c - v_c)/t_1 = v_c/t_1$

For work that shows an understanding of how to determine the time that car X and car Y each spend accelerating 1 point

For work that shows an understanding of how to determine the time that car Y spends at constant speed 1 point

For correctly determining the total straightaway times for each car 1 point

Calculating the time for car X to travel one straightaway:

$$\frac{d}{2} = v_c t_1 + \frac{1}{2} a t_1^2, a = (2v_c - v_c)/t_1 = v_c/t_1$$

$$t_1 = \frac{d}{3v_c} = \frac{t_c}{3}, \text{ total time is } \frac{2t_c}{3}$$

Calculating the time for car Y to travel one straightaway:

Doing the calculation shown above using the distance of acceleration $d/4$ gives the result that one section of acceleration takes a time $t_c/6$.

The time for car Y to travel one constant speed section on the straightaway is $(d/2)/2v_c = (t_c/4)$.

Adding three segments to get the total time for one straightaway gives $7t_c/12$.

The calculations show that car Y takes less time on a straightaway, and both cars take the same time on the curves, so car Y overall takes less time.

(c) (2 points)

For linking math to one aspect of qualitative reasoning that explains the difference in times 1 point

For linking math to all other qualitative reasoning that explains the difference in times 1 point

Examples:

The only difference in the calculations for the time of one segment of linear acceleration is the difference in distances. That shows that car X takes longer to accelerate. The equation $(d/2)/2v_c = (t_c/4)$ corresponds to car Y traveling for a time at top speed.

Substituting $a = v_c/t_1$ into the displacement equation in part (b) ii gives $D = (3/2)v_c t_1$. This shows that a car takes less time to reach its maximum speed when it accelerates over a shorter distance. This means Car Y reaches its maximum speed more quickly and therefore spends more time at its maximum speed than Car X does, as argued in part (b) i.

Sample Questions for the AP Physics 2 Exam

Multiple-Choice Questions

Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

Questions 1–3 refer to the following material.

An isolated, neutral lambda particle (Λ^0) is moving to the right with speed v . It then decays into a proton and a pion ($\Lambda^0 \rightarrow p^+ + \pi^-$). The following are the masses of the three particles:

Lambda: $1115.7 \text{ MeV}/c^2$

Proton: $938.3 \text{ MeV}/c^2$

Pion: $139.6 \text{ MeV}/c^2$

- How much energy is released when the Λ^0 decays?
 - 2193.6 MeV
 - 1914.4 MeV
 - 317.0 MeV
 - 37.8 MeV

Essential Knowledge	4.C.4: Mass can be converted into energy, and energy can be converted into mass.
Learning Objectives	4.C.4.1: The student is able to apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.
Science Practices	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

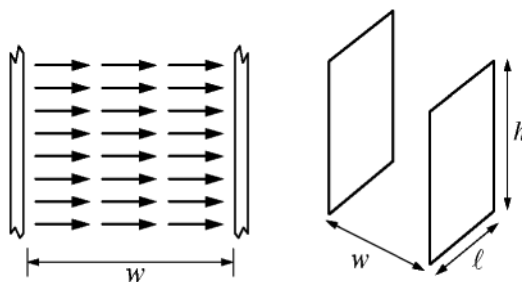
2. Which of the following indicates how the total linear momentum of the particles after the decay compares to the linear momentum of the Λ^0 before the decay and explains why?
- (A) The momentum is in the same direction but has a smaller magnitude because the proton and pion have opposite charges and attract each other.
 - (B) The momentum is in the same direction but has a smaller magnitude because the proton and pion are emitted in opposite directions.
 - (C) The momentum is in the same direction and has the same magnitude because no external force acts on the system of particles.
 - (D) The momentum is in the same direction and has the same magnitude because the work done by the strong force is greater than the energy emitted during the decay.

Essential Knowledge	5.D.3: The velocity of the center of mass of the system cannot be changed by an interaction within the system.
Learning Objectives	5.D.3.3: The student is able to make predictions about the velocity of the center of mass for interactions within a defined two-dimensional system.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

3. At some later time, the proton and pion are both moving to the right in the plane of the page when they enter a magnetic field directed out of the page. Which of the following describes the directions of the magnetic forces on the proton and pion at the instant they enter the field?
- (A) Proton: toward the top of the page
Pion: toward the top of the page
 - (B) Proton: toward the top of the page
Pion: toward the bottom of the page
 - (C) Proton: toward the bottom of the page
Pion: toward the bottom of the page
 - (D) Proton: toward the bottom of the page
Pion: toward the top of the page

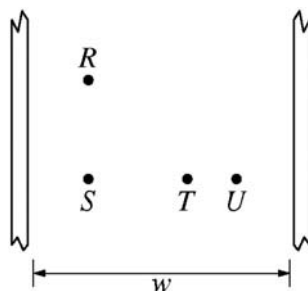
Essential Knowledge	3.C.3: A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.
Learning Objectives	3.C.3.1: The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively.

Questions 4–7 refer to the following material.



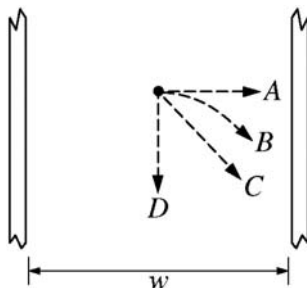
Note: Figure not drawn to scale.

The figure above on the left represents the horizontal electric field near the center of two large, vertical parallel plates near Earth's surface. The plates have height h and length ℓ , and they are separated by a distance w , as shown on the right. The field has magnitude E . A small object with mass m and charge $+q$, where $m = qE/g$, is released from rest at a point midway between the plates.



4. Points R , S , T , and U are located between the plates as shown in the figure above, with points R and T equidistant from point S . Let V_{RS} , V_{ST} , V_{TU} , and V_{RU} be the magnitudes of the electric potential differences between the pairs of points. How do the magnitudes of these potential differences compare?
- (A) $V_{RU} > V_{ST} > V_{TU} > V_{RS}$
- (B) $V_{RU} > (V_{RS} = V_{ST}) > V_{TU}$
- (C) $V_{RS} > V_{TU} > V_{ST} > V_{RU}$
- (D) $V_{TU} > (V_{RS} = V_{ST}) > V_{RU}$

Essential Knowledge	2.C.5: Between two oppositely charged parallel plates with uniformly distributed electric charge, at points far from the edges of the plates, the electric field is perpendicular to the plates and is constant in both magnitude and direction.
Learning Objectives	2.C.5.2: The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.
Science Practices	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.



5. After the object is released from rest, which of the paths shown in the figure above is a possible trajectory for the object?
- (A) A
(B) B
(C) C
(D) D

Essential Knowledge	2.C.1: The magnitude of the electric force F exerted on an object with electric charge q by an electric field E is $\vec{F} = q\vec{E}$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates. 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
Learning Objectives	2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation. 3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations.

Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

6. Under which of the following new conditions could the gravitational force on the object be neglected?

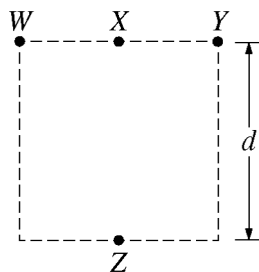
- (A) $h \gg w$
 (B) $q \gg m$
 (C) $qE \gg mg$
 (D) $Eh \gg Ew$

Essential Knowledge	3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
Learning Objectives	3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. 3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

7. The speed of a proton moving in an electric field changes from v_i to v_f over a certain time interval. Let the mass and charge of the proton be denoted as m_p and e . Through what potential difference did the proton move during the interval?

- (A) $\frac{m_p}{2}(v_f^2 - v_i^2)$
 (B) $\frac{m_p}{2e}(v_f^2 - v_i^2)$
 (C) $\frac{m_p}{2}(v_f - v_i)$
 (D) $\frac{m_p}{2e}(v_f - v_i)$

Essential Knowledge	2.C.1: The magnitude of the electric force F exerted on an object with electric charge q by an electric field E is $\vec{F} = q\vec{E}$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates. 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.
Learning Objectives	2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation. 2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities. 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

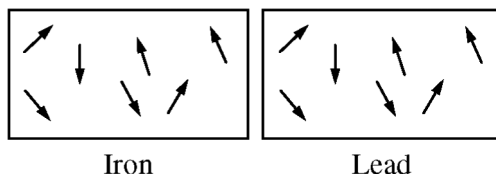


8. Four objects, each with charge $+q$, are held fixed on a square with sides of length d , as shown in the figure above. Objects X and Z are at the midpoints of the sides of the square. The electrostatic force exerted by object W on object X is F . What is the magnitude of the net force exerted on object X by objects W , Y , and Z ?
- (A) $\frac{F}{4}$
- (B) $\frac{F}{2}$
- (C) $\frac{9F}{4}$
- (D) $3F$

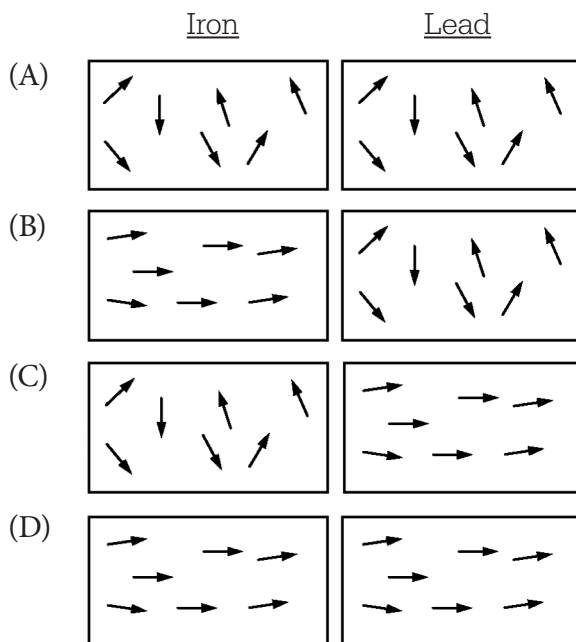
Essential Knowledge	3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. 3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
Learning Objectives	3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. 3.C.2.3: The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2 to 4 point charges, though more are permitted in situations of high symmetry).
Science Practices	1.1: The student can <i>create representations and models</i> of natural or man-made phenomena and systems in the domain. 1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.

9. Isolines of potential are drawn for the gravitational field of the Sun-Mercury system. The pattern of the isolines is identical to the pattern of equipotential lines for a system of two electrically charged objects with which of the following properties?
- (A) The charges have the same sign and the same magnitude.
 - (B) The charges have the same sign and different magnitudes.
 - (C) The charges have opposite signs and the same magnitude.
 - (D) The charges have opposite signs and different magnitudes.

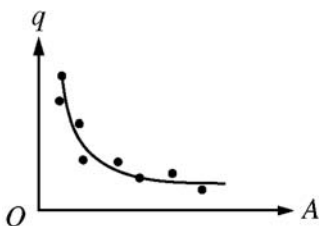
Essential Knowledge	2.E.1: Isolines on a topographic (elevation) map describe lines of approximately equal gravitational potential energy per unit mass (gravitational equipotential). As the distance between two different isolines decreases, the steepness of the surface increases. 2.E.2: Isolines in a region where an electric field exists represent lines of equal electric potential referred to as equipotential lines.
Learning Objectives	2.E.1.1: The student is able to construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential. 2.E.2.2: The student is able to predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



10. The figure above represents the random orientations of the magnetic dipoles in a block of iron and a block of lead. Iron is ferromagnetic and lead is diamagnetic. The two blocks are placed in a magnetic field that points to the right. Which of the following best represents the orientations of the dipoles when the field is present?



Essential Knowledge	2.D.3: A magnetic dipole placed in a magnetic field, such as the ones created by a magnet or the Earth, will tend to align with the magnetic field vector. 4.E.1: The magnetic properties of some materials can be affected by magnetic fields at the system. Students should focus on the underlying concepts and not the use of the vocabulary.
Learning Objectives	2.D.3.1: The student is able to describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet. 4.E.1.1: The student is able to use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by magnetic properties of other objects in the system.
Science Practices	1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain. 1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively.



11. Students are performing an experiment to determine how changing the area of the plates of a parallel-plate capacitor affects its behavior in a circuit. They connect a capacitor with plate area A to a battery and allow it to become fully charged. They take measurements that they believe will allow them to calculate the charge q on one plate of the capacitor. The students then repeat the procedure with other capacitors. The capacitors each have a different plate area but are otherwise identical. The students plot the calculated charge q as a function of plate area A . Their results, including a best fit to the data, are represented above. Is this graph a reasonably accurate representation of the relationship between q and A ?
- (A) Yes, because the relationship should result in a graph that is curved and decreasing.
 - (B) No, because the relationship should result in a graph that is linear and decreasing.
 - (C) No, because the relationship should result in a graph that is linear and increasing.
 - (D) No, because the relationship should result in a graph that is curved and increasing.

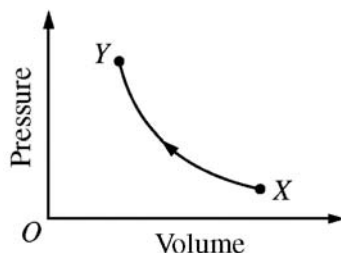
Essential Knowledge	4.E.4: The resistance of a resistor and the capacitance of a capacitor can be understood from the basic properties of electric fields and forces as well as the properties of materials and their geometry. 4.E.5: The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.
Learning Objectives	4.E.4.3: The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.
Science Practices	5.1: The student can <i>analyze data</i> to identify patterns or relationships.

12. Some students experimenting with an uncharged metal sphere want to give the sphere a net charge using a charged aluminum pie plate. Which of the following steps would give the sphere a net charge of the same sign as the pie plate?
- (A) Bringing the pie plate close to, but not touching the metal sphere, then moving the pie plate away
 - (B) Bringing the pie plate close to, but not touching, the metal sphere, then momentarily touching a grounding wire to the metal sphere
 - (C) Bringing the pie plate close to, but not touching, the metal sphere, then momentarily touching a grounding wire to the pie plate
 - (D) Touching the pie plate to the metal sphere

Essential Knowledge	4.E.3: The charge distribution in a system can be altered by the effects of electric forces produced by a charged object. 5.C.2: The exchange of electric charges among a set of objects in a system conserves electric charge.
Learning Objectives	4.E.3.5: The student is able to explain and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. 5.C.2.2: The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data.
Science Practices	4.2: The student can <i>design a plan</i> for collecting data to answer a particular scientific question.

13. An ideal fluid is flowing with a speed of 12 cm/s through a pipe of diameter 5 cm. The pipe splits into three smaller pipes, each with a diameter of 2 cm. What is the speed of the fluid in the smaller pipes?
- (A) 4 cm/s
 - (B) 12 cm/s
 - (C) 25 cm/s
 - (D) 75 cm/s

Essential Knowledge	5.F.1: The continuity equation describes conservation of mass flow rate in fluids. Examples should include volume rate of flow and mass flow rate.
Learning Objectives	5.F.1.1: The student is able to make calculations of quantities related to flow of a fluid using mass conservation principles (the continuity equation).
Science Practices	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena.



14. The graph above shows the pressure as a function of volume for a sample of gas that is taken from state X to state Y at constant temperature. Which of the following indicates the sign of the work done on the gas, and whether thermal energy is absorbed or released by the gas during this process?

	<u>Work Done</u>	<u>Thermal Energy</u>
(A)	Positive	Absorbed
(B)	Positive	Released
(C)	Negative	Absorbed
(D)	Negative	Released

Essential Knowledge	5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.
Learning Objectives	5.B.7.1: The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

15. Two samples of ideal gas in separate containers have the same number of molecules and the same temperature, but the molecular mass of gas X is greater than that of gas Y . Which of the following correctly compares the average speed of the molecules of the gases and the average force the gases exert on their respective containers?

	<u>Average Speed of Molecules</u>	<u>Average Force on Container</u>
(A)	Greater for gas X	Greater for gas X
(B)	Greater for gas X	The forces cannot be compared without knowing the volumes of the gases.
(C)	Greater for gas Y	Greater for gas Y
(D)	Greater for gas Y	The forces cannot be compared without knowing the volumes of the gases.

Essential Knowledge	7.A.1: The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum, the impulse, of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container. 7.A.2: The temperature of a system characterizes the average kinetic energy of its molecules.
Learning Objectives	7.A.1.1: The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. 7.A.2.2: The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.1: The student can <i>connect phenomena and models</i> across spatial and temporal scales. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

16. Three different gas samples that have the same number of molecules and are at room temperature are kept at different pressures. A lab technician has determined the molecular mass of each gas and recorded the pressure and molecular mass of each sample in the table below.

Gas	Molecular Mass (u)	Pressure (¥100 kPa)
X	2.0	6.0
Y	4.0	12
Z	40	1.0

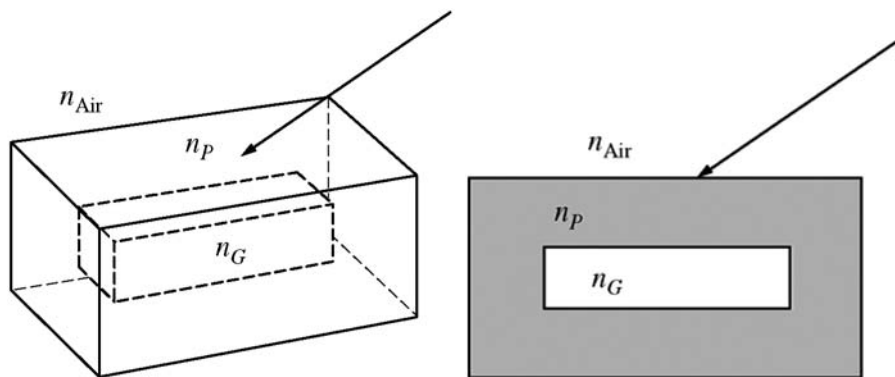
Which of the following ranks the density ρ of the gas samples?

- (A) $\rho_X = \rho_Y > \rho_Z$
- (B) $\rho_Y > \rho_Z > \rho_X$
- (C) $\rho_Z > \rho_X = \rho_Y$
- (D) $\rho_Z > \rho_Y > \rho_X$

Essential Knowledge	1.A.5: Systems have properties determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an <i>object</i>. 1.E.1: Matter has a property called density.
Learning Objectives	1.A.5.2: The student is able to construct representations of how the properties of a system are determined by the interactions of its constituent substructures. 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.1: The student can <i>connect phenomena and models</i> across spatial and temporal scales.

17. Light from a source that produces a single frequency passes through a single slit *A*. The diffraction pattern on a screen is observed. Slit *A* is then replaced by slit *B*, and the new pattern is observed to have fringes that are more closely spaced than those in the first pattern. Which of the following is a possible explanation for why the spacings are different?
- (A) Slit *A* is wider than slit *B*.
 - (B) Slit *B* is wider than slit *A*.
 - (C) The distance between the light source and the slit is greater for slit *A* than for slit *B*.
 - (D) The distance between the light source and the slit is greater for slit *B* than for slit *A*.

Essential Knowledge	6.C.2: When waves pass through an opening whose dimensions are comparable to the wavelength, a diffraction pattern can be observed.
Learning Objectives	6.C.2.1: The student is able to make claims about the diffraction pattern produced when a wave passes through a small opening and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



18. Students in a lab group are given a plastic block with a hollow space in the middle, as shown in the figures above. The index of refraction n_p of the plastic is known. The hollow space is filled with a gas, and the students are asked to collect the data needed to find the index of refraction n_G of the gas. The arrow represents a light beam that they shine into the plastic. They take the following set of measurements:

Angle of incidence of the light in the air above the plastic block	30°
Angle of refraction of the beam as it enters the plastic from the air	45°
Angle of refraction of the beam as it enters the plastic from the gas	45°

The three measurements are shared with a second lab group. Can the second group determine a value of n_G from only this data?

- (A) Yes, because they have information about the beam in air and in the plastic above the gas.
- (B) Yes, because they have information about the beam on both sides of the gas.
- (C) No, because they need additional information to determine the angle of the beam in the gas.
- (D) No, because they do not have multiple data points to analyze.

Essential Knowledge	6.E.3: When light travels across a boundary from one transparent material to another, the speed of propagation changes. At a non-normal incident angle, the path of the light ray bends closer to the perpendicular in the optically slower substance. This is called refraction.
Learning Objectives	6.E.3.2: The student is able to plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law).
Science Practices	5.3: The student can <i>evaluate the evidence provided by data sets</i> in relation to a particular scientific question.

19. The ground state of a certain type of atom has energy $-E_0$. What is the wavelength of a photon with enough energy to ionize an atom in the ground state and give the ejected electron a kinetic energy of $2E_0$?

(A) $\frac{hc}{3E_0}$

(B) $\frac{hc}{2E_0}$

(C) $\frac{hc}{E_0}$

(D) $\frac{2hc}{E_0}$

Essential Knowledge	5.B.8: Energy transfer occurs when photons are absorbed or emitted, for example, by atoms or nuclei.
Learning Objectives	5.B.8.1: The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.
Science Practices	1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

20. A hypothetical one-electron atom in its highest excited state can only emit photons of energy $2E$, $3E$, and $5E$. Which of the following is a possible energy-level diagram for the atom?

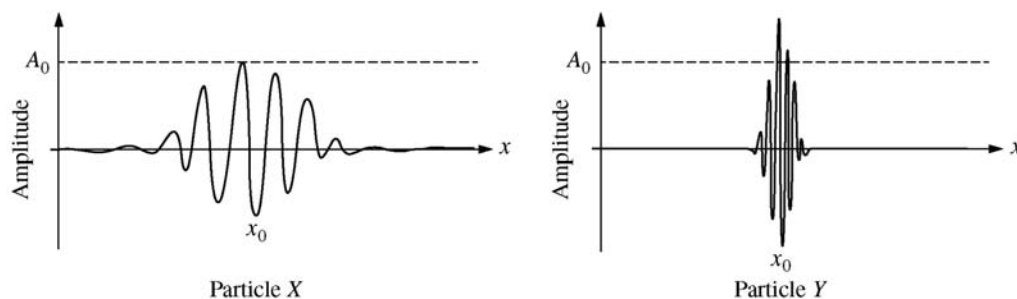
(A) $\begin{array}{l} \text{————— } 5E \\ \text{————— } 3E \\ \text{————— } 0 \end{array}$

(B) $\begin{array}{l} \text{————— } 3E \\ \text{————— } 2E \\ \text{————— } 0 \end{array}$

(C) $\begin{array}{l} \text{————— } 5E \\ \text{————— } 3E \\ \text{————— } 2E \\ \text{————— } 0 \end{array}$

(D) $\begin{array}{l} \text{————— } 10E \\ \text{————— } 8E \\ \text{————— } 5E \\ \text{————— } 0 \end{array}$

Essential Knowledge	1.A.4: Atoms have internal structures that determine their properties. 5.B.8: Energy transfer occurs when photons are absorbed or emitted, for example, by atoms or nuclei.
Learning Objectives	1.A.4.1: The student is able to construct representations of the energy level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated. 5.B.8.1: The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.
Science Practices	1.1: The student can <i>create representations and models</i> of natural or man-made phenomena and systems in the domain. 1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain.



21. The figure above shows graphical representations of the wave functions of two particles, X and Y, that are moving in the positive x -direction. The maximum amplitude of particle X's wave function is A_0 . Which particle has a greater probability of being located at position x_0 at this instant, and why?
- (A) Particle X, because the wave function of particle X spends more time passing through x_0 than the wave function of particle Y
 - (B) Particle X, because the wave function of particle X has a longer wavelength than the wave function of particle Y
 - (C) Particle Y, because the wave function of particle Y is narrower than the wave function of particle X
 - (D) Particle Y, because the wave function of particle Y has a greater amplitude near x_0 than the wave function of particle X

Essential Knowledge	7.C.1: The probabilistic description of matter is modeled by a wave function, which can be assigned to an object and used to describe its motion and interactions. The absolute value of the wave function is related to the probability of finding a particle in some spatial region. (Qualitative treatment only, using graphical analysis.)
Learning Objectives	7.C.1.1: The student is able to use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region.
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively.

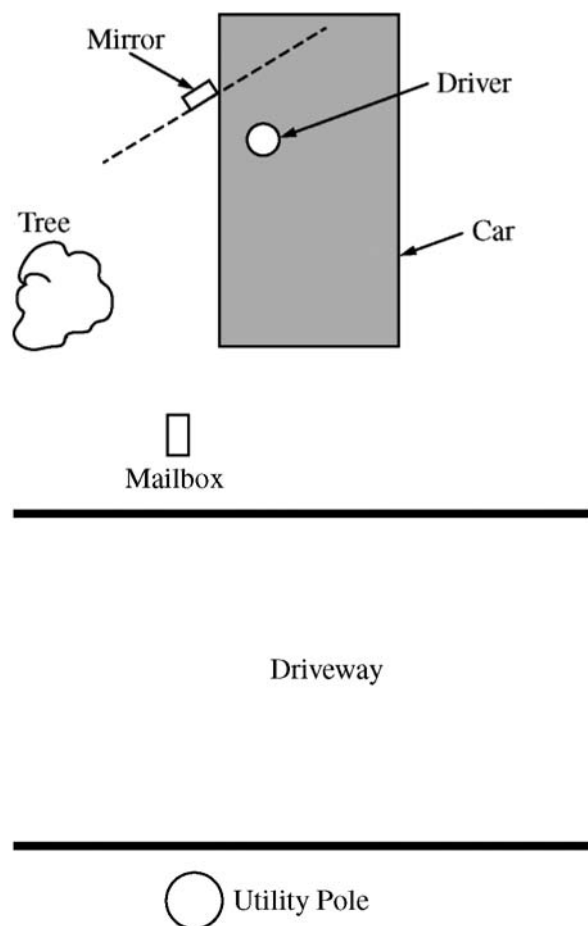
Directions: For questions 22–25 below, two of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

22. On a day that is warm and sunny, a car is parked in a location where there is no shade. The car's windows are closed. The air inside the car becomes noticeably warmer than the air outside. Which of the following factors contribute to the higher temperature? Select two answers.
- (A) Hotter air rises to the roof of the car and cooler air falls to the floor.
 - (B) The body of the car insulates the air inside the car.
 - (C) Electromagnetic radiation from the Sun enters the car and is absorbed by the materials inside.
 - (D) The body of the car reflects electromagnetic radiation.

Essential Knowledge	5.B.6: Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.
Learning Objectives	5.B.6.1: The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.
Science Practices	1.2: The student can <i>describe representations and models</i> of natural or man-made phenomena and systems in the domain.

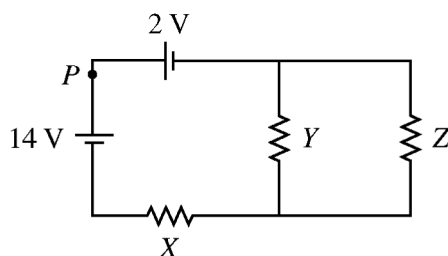
23. A fixed amount of ideal gas is kept in a container of fixed volume. The absolute pressure P , in pascals, of the gas is plotted as a function of its temperature T , in degrees Celsius. Which of the following are properties of a best fit curve to the data? Select two answers.
- (A) Having a positive slope
 - (B) Passing through the origin
 - (C) Having zero pressure at a certain negative temperature
 - (D) Approaching zero pressure as temperature approaches infinity

Essential Knowledge	7.A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V), are related by the equation $PV = nRT$.
Learning Objectives	7.A.3.1: The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. 7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$.
Science Practices	5.1: The student can <i>analyze data</i> to identify patterns or relationships. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.



24. A driver is backing a car off a lawn into a driveway while using the side-view mirror to check for obstacles. The figure above shows a top view of the car and some objects near the car. The mirror is a plane mirror, and the dashed line shows the angle of its plane. Which of the following should the driver be able to see in the mirror by just turning her head without moving her head from the position shown? Select two answers.
- (A) Herself
 - (B) The tree
 - (C) The mailbox
 - (D) The utility pole

Essential Knowledge	6.E.2: When light hits a smooth reflecting surface at an angle, it reflects at the same angle on the other side of the line perpendicular to the surface (specular reflection); this law of reflection accounts for the size and location of images seen in mirrors.
Learning Objectives	6.E.2.1: The student is able to make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



25. The figure above shows a circuit containing two batteries and three identical resistors with resistance R . Which of the following changes to the circuit will result in an increase in the current at point P ? Select two answers.
- (A) Reversing the connections to the 14 V battery
 - (B) Removing the 2 V battery and connecting the wires to close the left loop
 - (C) Rearranging the resistors so all three are in series
 - (D) Removing the branch containing resistor Z

Essential Knowledge	4.E.5: The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors. 5.B.9: Kirchhoff's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.] 5.C.3: Kirchhoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel.
Learning Objectives	4.E.5.2: The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. 5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. 5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation.
Science Practices	6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

Answers to Multiple-Choice Questions

1. D	9. B	17. B	25. A, B
2. C	10. B	18. C	
3. D	11. C	19. A	
4. A	12. D	20. A	
5. C	13. C	21. D	
6. C	14. B	22. B, C	
7. B	15. D	23. A, C	
8. A	16. B	24. C, D	

Free-Response Questions

Directions: Question 1 is a short free-response question that requires about 15–20 minutes to answer and is worth 10 points. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

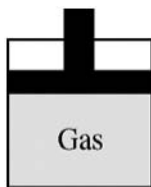
1. Some scientists want to perform electron diffraction experiments on crystals that have an intermolecular spacing of about 10^{-10} m. They have two processes by which they can produce energetic electrons that can strike the crystals.

Process 1 is the beta decay of potassium into calcium: $^{40}\text{K} \rightarrow ^{40}\text{Ca} + e^- + \bar{\nu}_e$. The mass of ^{40}K is 39.964000 u and the mass of ^{40}Ca is 39.962591 u. As an approximation, assume that the mass of the neutrino is negligible and that all the decay energy is acquired by the electron.

Process 2 is the emission of electrons when electromagnetic radiation of wavelength 7.5 nm shines on a copper surface with work function 4.7 eV.

- Describe a single criterion for determining whether each of these processes can be used to produce electrons for the diffraction experiments.
- Determine whether each of these processes could be used to produce electrons appropriate for the diffraction experiments. Justify your answers mathematically.

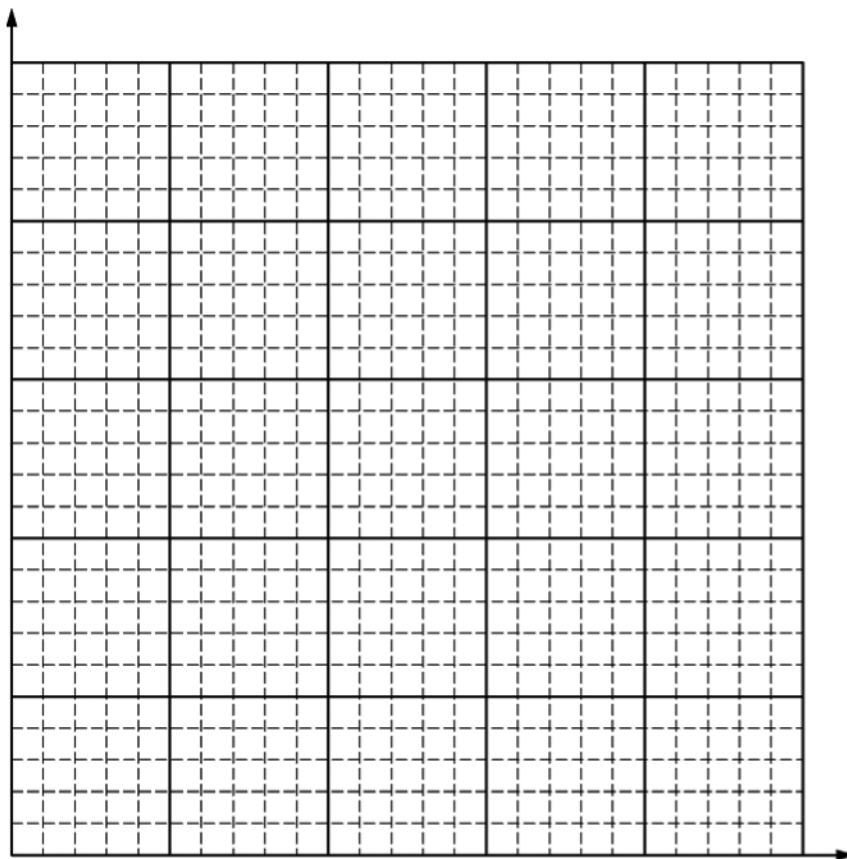
Essential Knowledge	4.C.4: Mass can be converted into energy and energy can be converted into mass. 6.F.3: Photons are individual energy packets of electromagnetic waves, with $E_{\text{photon}} = hf$, where h is Planck's constant and f is the frequency of the associated light wave. 6.G.2: Under certain regimes of energy or distance, matter can be modeled as a wave. The behavior in these regimes is described by quantum mechanics.
Learning Objectives	4.C.4.1: The student is able to apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale. 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. 6.G.2.2: The student is able to predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima), based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal. (de Broglie wavelength need not be given, so students may need to obtain it.)
Science Practices	2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



2. The figure above shows a clear plastic container with a movable piston that contains a fixed amount of gas. A group of students is asked to determine whether the gas is ideal. The students design and conduct an experiment. They measure the three quantities recorded in the data table below.

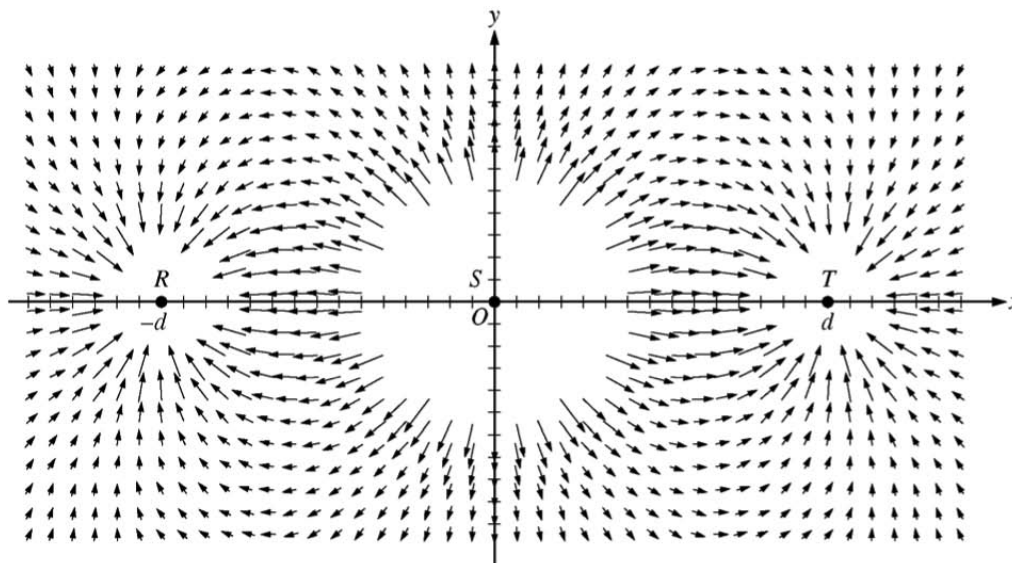
Trial	Absolute Gas Pressure ($\times 10^5$ Pa)	Volume (m^3)	Temperature (K)		
1	1.1	0.020	270		
2	1.4	0.016	270		
3	1.9	0.012	270		
4	2.2	0.010	270		
5	2.8	0.008	270		
6	1.2	0.020	290		
7	1.5	0.016	290		
8	2.0	0.012	290		
9	2.4	0.010	290		
10	3.0	0.008	290		
11	1.3	0.020	310		
12	1.6	0.016	310		
13	2.1	0.012	310		
14	2.6	0.010	310		
15	3.2	0.008	310		

- (a) Describe an experimental procedure the group of students could have used to obtain these data. Include all the equipment needed and a labeled diagram of the setup. Clearly indicate what measurements would be taken and how each of the manipulated variables would be varied. Include enough detail so that someone else could carry out the procedure.
- (b) Select a set of data points from the table and plot those points on the axes below to create a graph to determine whether the gas exhibits properties of an ideal gas. Fill in blank columns in the table for any quantities you graph other than the given data. Label the axes and indicate the scale for each. Draw a best-fit line or curve through your data points.



- (c) Indicate whether the gas exhibits properties of an ideal gas, and explain what characteristic of your graph provides the evidence.
- (d) The students repeat their experiment with an identical container that contains half as much gas. They take data for the same values of volume and temperature as in the table. Would the new data result in a different conclusion about whether the gas is ideal? Justify your answer in terms of interactions between the molecules of the gas and the container walls.

Essential Knowledge	5.B.7: The first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative. 7.A.1: The pressure of a system determines the force that the system exerts on the walls of its container and is a measure of the average change in the momentum, the impulse, of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container. 7.A.3: In an ideal gas, the macroscopic (average) pressure (P), temperature (T), and volume (V) are related by the equation $PV = nRT$.
Learning Objectives	5.B.7.2: The student is able to create a plot of pressure versus volume for a thermodynamic process from given data. 7.A.1.1: The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. 7.A.3.2: The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables. 7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$.
Science Practices	1.1: The student can <i>create representations and models</i> of natural or man-made phenomena and systems in the domain. 4.2: The student can <i>design a plan</i> for collecting data to answer a particular scientific question. 5.1: The student can <i>analyze data</i> to identify patterns or relationships. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models. 7.2: The student can <i>connect concepts</i> in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.



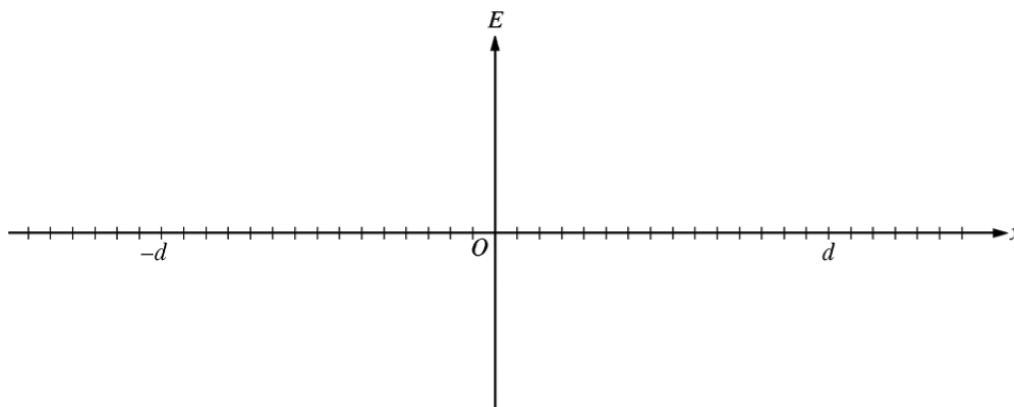
3. The figure above represents the electric field in the vicinity of three small charged objects, R , S , and T . The objects have charges $-q$, $+2q$, and $-q$, respectively, and are located on the x -axis at $-d$, 0 , and d . Field vectors of very large magnitude are omitted for clarity.

(a)

- i. Briefly describe the characteristics of the field diagram that indicate that the sign of the charges of objects R and T is negative and that the sign of the charge of object S is positive.
- ii. Briefly describe the characteristics of the field diagram that indicate that the magnitudes of the charges of objects R and T are equal and that the magnitude of the charge of object S is about twice that of objects R and T .

For the following parts, an electric field directed to the right is defined to be positive.

- (b) On the axes below, sketch a graph of the electric field E along the x -axis as a function of position x .



- (c) Write an expression for the electric field E along the x -axis as a function of position x in the region between objects S and T in terms of q , d , and fundamental constants, as appropriate.
- (d) Your classmate tells you there is a point between S and T where the electric field is zero. Determine whether this statement is true, and explain your reasoning using two of the representations from parts (a), (b), or (c).

Essential Knowledge

2.C.1: The magnitude of the electric force $\vec{F}$ exerted on an object with electric charge q by an electric field $\vec{E}$ is $\vec{F} = q\vec{E}$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

2.C.2: The magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field. This includes positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

2.C.4: The electric field around dipoles and other systems of electrically charged objects (that can be modeled as point objects) is found by vector addition of the field of each individual object. Electric dipoles are treated qualitatively in this course as a teaching analogy to facilitate student understanding of magnetic dipoles.

3.C.2: Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.

Learning Objectives	2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities. 2.C.2.1: The student is able to qualitatively and semiquantitatively apply the vector relationship between the electric field and the net electric charge creating that field. 2.C.4.2: The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points. 3.C.2.1: The student is able to use Coulomb’s law qualitatively and quantitatively to make predictions about the interaction between two electric point charges (interactions between collections of electric point charges are not covered in Physics 1 and instead are restricted to Physics 2). 3.C.2.3: The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2 to 4 point charges, though more are permitted in situations of high symmetry).
Science Practices	1.4: The student can <i>use representations and models</i> to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can <i>apply mathematical routines</i> to quantities that describe natural phenomena. 6.4: The student can <i>make claims and predictions about natural phenomena</i> based on scientific theories and models.

Scoring Guidelines

Scoring Guidelines for Free-Response Question 1 (10 points)

(a) (2 points)

For indicating an appropriate quantity to compare — either length or energy 1 point

For indicating the appropriate specific quantities to compare: 1 point

de Broglie wavelengths of electrons and crystal spacing

OR

kinetic energy of electrons and kinetic energy needed to have a de Broglie wavelength equal to the crystal spacing

Example: The energy of electrons produced by each method is comparable to the energy of electrons with de Broglie wavelengths corresponding to the crystal spacing.

(b) (8 points)

For converting the electron energies to de Broglie wavelengths 2 points

OR

using the crystal spacing as a de Broglie wavelength to determine the required electron energy

Decay process

For determining the mass difference of the atoms 1 point

For converting the mass difference to energy 1 point

For correctly evaluating the energy against the crystal 1 point

Photoelectric process

For determining the energy of the incident light 1 point

For determining the maximum kinetic energy K of the ejected electrons 1 point

For correctly evaluating the kinetic energy against the crystal 1 point

Example:

Determine the electron kinetic energy needed for the electron to have a de Broglie wavelength of 10^{-10} m:

$$10^{-10} \text{ m} = (6.63 \times 10^{-34} \text{ J}\cdot\text{s})/p$$

$$K = \frac{1}{2}mv^2 = \frac{1}{2} \frac{m^2 v^2}{m} = \frac{p^2}{2m}$$

$$K = p^2/2m = \left(\frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{10^{-10}} \right)^2 \frac{1}{2(9.11 \times 10^{-31} \text{ kg})} = 2.4 \times 10^{-17} \text{ J} = 150 \text{ eV}$$

Determine the energy released by the decay reaction, which is converted to kinetic energy of the electron:

$$\begin{aligned} & \left[(39.964000 \text{ u} - 39.962591 \text{ u})(1.66 \times 10^{-27} \text{ kg/u}) - 9.11 \times 10^{-31} \text{ kg} \right] c^2 \\ & = 1.285 \times 10^{-13} \text{ J} \end{aligned}$$

NOTE: This is four orders of magnitude larger than $2.4 \times 10^{-17} \text{ J}$, so the wavelength will be two orders of magnitude smaller than desired. This process will not work well.

Determine the maximum kinetic energy K of electrons emitted in the photoelectric effect:

$$K_{\text{max}} = hf - \phi$$

$$f = c/\lambda = 3 \times 10^8 / 7.5 \times 10^{-9} = 4 \times 10^{16} \text{ Hz}$$

$$K_{\text{max}} = (4.14 \times 10^{-15} \text{ eV}\cdot\text{s})(4 \times 10^{16} \text{ Hz}) - 4.7 \text{ eV}$$

$$K_{\text{max}} = 165.6 \text{ eV} - 4.7 \text{ eV} = 160.9 \text{ eV}$$

NOTE: This is comparable to 150 eV, so this process will work.

Scoring Guidelines for Free-Response Question 2 (12 points)

(a) (4 points)

For clearly indicating which variables are manipulated and which are controlled	1 point
For clearly describing an experimental setup	1 point
For an experimental setup that allows the manipulation and control of the indicated variables	1 point
For an experimental setup that allows multiple measurements of P , V , and T	1 point

Example:

Hold temperature constant while volume is manipulated and pressure is measured. Then change the temperature and hold it constant again while volume is manipulated and pressure is measured, etc. To do this: Measure the cross-sectional area of the piston in units of meters cubed. Put the container in an insulated bath that can be filled with water at one of the three different temperatures. Fill the bath with water. Allow some time for the gas in the container to equilibrate in temperature with the surrounding water bath. Measure the temperature of the bath. Measure six fixed heights, in units of meters, along the side of the container. Slowly add weights to the top of the piston so that the piston can be depressed to each height without changing the temperature. Multiply the height by the cross-sectional area of the piston to get the volume.

Divide the weight in newtons by the cross-sectional area of the piston to get the pressure and add atmospheric pressure and the pressure from the piston. Repeat the process twice using water at each of the other two temperatures.

(b) (4 points)

For plotting appropriate quantities to examine ideal behavior 1 point

For labeling and scaling the axes 1 point

For plotting the data reasonably correctly 1 point

For plotting a set of data with one variable controlled and drawing a reasonable best-fit line 1 point

OR

plotting more than one data set and more than one reasonable best-fit line

Example:

Plot P as a function of $1/V$ for a single value of T . Draw a best-fit line through the data.

(c) (2 points)

For a correct conclusion with a reasonable attempt at an explanation 1 point

For a correct explanation relating to characteristics exhibited in the ideal gas law 1 point

Example:

$PV = nRT$, so a graph of P versus $1/V$ for an ideal gas should be linear if n and T are held constant. In the graphed set of data, n and T are held constant and the graph is linear, so there is evidence that the gas is ideal.

(d) (2 points)

For indicating that the conclusion would be the same, since the amount of gas does not affect the relationship between the state variables 1 point

For indicating that the rate of collision with the walls will be lower, so the pressure would be lower 1 point

Example:

No, the conclusion would be the same. Reducing the amount of gas by half would result in there being half the rate of collisions with the container walls and half as much weight needed to compress the gas to the same volume at the same temperature. The graph of P as a function of $1/V$ would still be linear, but with half the slope.

Scoring Guidelines for Free-Response Question 3 (12 points)

(a) (3 points)

i)

For indicating that the direction of the field vectors is the telling characteristic and describing how they indicate negative and positive charge 1 point

Example: The direction of the field vectors. Field vectors near objects point toward negatively charged objects and away from positively charged objects.

ii)

For indicating that the size and distance of the closest field vectors are the telling characteristics 1 point

For describing how the size and distance of the closest field vectors indicate the magnitudes of the charges 1 point

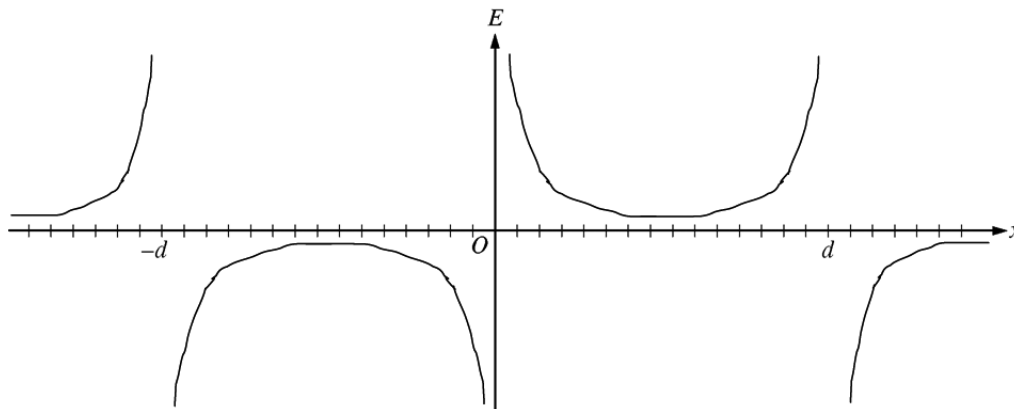
Field vectors nearest R and T are at about the same distance and have approximately the same length, so the magnitude of their charge is equal.

Field vectors nearest S have approximately the same length as field vectors nearest R and T , but the square of the distance to the field vectors nearest S is about twice the square of the distance to the field vectors nearest R and T – 36 (6 tic marks squared) compared with 16 (4 tic marks squared). So the magnitude of the charge of S is twice the magnitude of the charges of R and T .

Example:

The vectors closest to R and T are about the same length and start at about the same distance. $q_R/d^2 = q_T/d^2$, so the charge on R is about the same as the charge on T . The closest vectors around S are about the same length as those around R and T . The vectors near S start at about 6 units away, while vectors near R and T start at about 4 units. $q_R/d^2 = q_S/D^2$, so $q_S/q_R = D^2/d^2 = 36/16 = 2.25$, and so the charge on S is about twice that on R and T .

(b) (3 points)

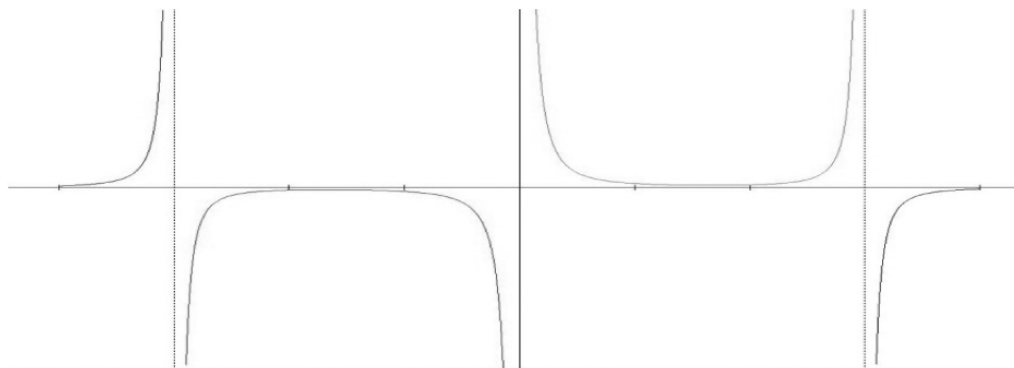


For showing reasonably close to asymptotic behavior on both sides of the charge positions 1 point

For a general U shape between the charges that does not touch the x-axis 1 point

For all signs consistent with the vector map 1 point

The following shows a more exact plot. The scale is set to show the asymptotic behavior, which masks the nonzero values between charges and at both sides of the range.



(c) (3 points)

For correctly associating charge values with positions 1 point

For using the correct sign and power in the expressions for the distance to each charge 1 point

For the correct sign for the direction of the field for each term 1 point

$$E = k \left[-\frac{q}{(d+x)^2} + \frac{2q}{(x)^2} + \frac{q}{(d-x)^2} \right]$$

(d) (3 points)

For indicating that the value of the electric field is nonzero for all values between S and T 1 point

For justifying the above using one of the representations 1 point

For justifying the above using a second representation 1 point

The following are the ideas that should be expressed for each representation:

- The vectors between S and T in the electric field diagram all have nonzero length
- The graph between S and T never crosses the x -axis
- The negative term of the equation in part (c) is either always smaller than the other terms in this region or never completely cancels them both

Example:

The statement is not true. The vector diagram shows field vectors in this region with nonzero length, and the vectors not shown have even greater lengths.

The equation in part (c) shows that when $0 < x < d$, the denominator of the negative term is always greater than the denominator of the third term, but the numerator is the same. So the negative term always has a smaller magnitude than the third term, and since the second term is positive, the sum of the terms is always positive.

Note: A response claiming that there is a zero value can receive credit if it is consistent with an incorrect response in either part (b) or (c).

Appendix: AP Physics 1 and 2 Equations and Constants

Table of Information and Equation Tables for AP Physics 1 and 2 Exams

The accompanying Table of Information and equation tables will be provided to students when they take the AP Physics 1 and 2 Exams. Therefore, students may NOT bring their own copies of these tables to the exam room, although they may use them throughout the year in their classes in order to become familiar with their content. **The headings list the effective date of the tables. That date will only be changed when there is a revision to any of the tables. Check the Physics course home pages on AP Central for the latest versions of these tables (apcentral.collegeboard.org).**

The Table of Information and the equation tables are printed near the front cover of both the multiple-choice section and the free-response section. The Table of Information is identical for both exams except for some of the conventions.

The equations in the tables express the relationships that are encountered most frequently in the AP Physics 1 and 2 courses and exams. However, the tables do not include all equations that might possibly be used. For example, they do not include many equations that can be derived by combining other equations in the tables. Nor do they include equations that are simply special cases of any that are in the tables. Students are responsible for understanding the physical principles that underlie each equation and for knowing the conditions for which each equation is applicable.

The equation tables are grouped in sections according to the major content category in which they appear. Within each section, the symbols used for the variables in that section are defined. However, in some cases the same symbol is used to represent different quantities in different tables. It should be noted that there is no uniform convention among textbooks for the symbols used in writing equations. The equation tables follow many common conventions, but in some cases consistency was sacrificed for the sake of clarity.

Some explanations about notation used in the equation tables:

1. The symbols used for physical constants are the same as those in the Table of Information and are defined in the Table of Information rather than in the right-hand columns of the equation tables.
2. Symbols with arrows above them represent vector quantities.
3. Subscripts on symbols in the equations are used to represent special cases of the variables defined in the right-hand columns.
4. The symbol Δ before a variable in an equation specifically indicates a change in the variable (e.g., final value minus initial value).
5. Several different symbols (e.g., d , r , s , h , ℓ) are used for linear dimensions such as length. The particular symbol used in an equation is one that is commonly used for that equation in textbooks.

ADVANCED PLACEMENT PHYSICS 1 TABLE OF INFORMATION, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant, $k = 1/4\pi\epsilon_0 = 9.0 \times 10^9$ N·m ² /C ²
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m ³ /kg·s ²
Speed of light, $c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s ²

UNIT SYMBOLS	meter, m	kelvin, K	watt, W	degree Celsius, °C
	kilogram, kg	hertz, Hz	coulomb, C	
	second, s	newton, N	volt, V	
	ampere, A	joule, J	ohm, Ω	

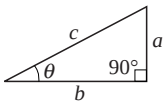
PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin \theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos \theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan \theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

- I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- II. Assume air resistance is negligible unless otherwise stated.
- III. In all situations, positive work is defined as work done on a system.
- IV. The direction of current is conventional current: the direction in which positive charge would drift.
- V. Assume all batteries and meters are ideal unless otherwise stated.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS, EFFECTIVE 2015

MECHANICS		ELECTRICITY	
$v_x = v_{x0} + a_x t$	a = acceleration	$ \vec{F}_E = k \frac{ q_1 q_2 }{r^2}$	A = area
$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$	d = distance	$I = \frac{\Delta q}{\Delta t}$	F = force
$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$	E = energy	$I = \frac{\rho \ell}{A}$	I = current
$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$	f = frequency	$I = \frac{\Delta V}{R}$	ℓ = length
$ \vec{F}_f \leq \mu \vec{F}_n $	F = force	$P = I \Delta V$	P = power
$a_c = \frac{v^2}{r}$	h = height	$R_s = \sum_i R_i$	q = charge
$\vec{p} = m\vec{v}$	I = rotational inertia	$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$	R = resistance
$\Delta \vec{p} = \vec{F} \Delta t$	K = kinetic energy		r = separation
$K = \frac{1}{2} m v^2$	k = spring constant		t = time
$\Delta E = W = F_{\parallel} d = F d \cos \theta$	L = angular momentum		V = electric potential
$P = \frac{\Delta E}{\Delta t}$	ℓ = length		ρ = resistivity
$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$	m = mass		
$\omega = \omega_0 + \alpha t$	P = power		
$x = A \cos(2\pi f t)$	p = momentum		
$\vec{a} = \frac{\sum \vec{F}}{I} = \frac{\vec{\tau}_{net}}{I}$	r = radius or separation		
$\tau = r_{\perp} F = r F \sin \theta$	T = period		
$L = I \omega$	t = time		
$\Delta L = \tau \Delta t$	U = potential energy		
$K = \frac{1}{2} I \omega^2$	V = volume		
$ \vec{F}_s = k \vec{x} $	v = speed		
$U_s = \frac{1}{2} k x^2$	W = work done on a system		
$\rho = \frac{m}{V}$	x = position		
	α = angular acceleration		
	μ = coefficient of friction		
	θ = angle		
	ρ = density		
	τ = torque		
	ω = angular speed		
	$\Delta U_g = mg \Delta y$		
	$T = \frac{2\pi}{\omega} = \frac{1}{f}$		
	$T_s = 2\pi \sqrt{\frac{m}{k}}$		
	$T_p = 2\pi \sqrt{\frac{\ell}{g}}$		
	$ \vec{F}_g = G \frac{m_1 m_2}{r^2}$		
	$\vec{g} = \frac{\vec{F}_g}{m}$		
	$U_G = -\frac{G m_1 m_2}{r}$		
ELECTRICITY		WAVES	
		$\lambda = \frac{v}{f}$	f = frequency
			v = speed
			λ = wavelength
GEOMETRY AND TRIGONOMETRY		GEOMETRY AND TRIGONOMETRY	
		Rectangle	A = area
		$A = bh$	C = circumference
		Triangle	V = volume
		$A = \frac{1}{2} bh$	S = surface area
		Circle	b = base
		$A = \pi r^2$	h = height
		$C = 2\pi r$	ℓ = length
		Rectangular solid	w = width
		$V = \ell wh$	r = radius
		Cylinder	
		$V = \pi r^2 \ell$	
		$S = 2\pi r \ell + 2\pi r^2$	
		Sphere	
		$V = \frac{4}{3} \pi r^3$	
		$S = 4\pi r^2$	
			Right triangle
			$c^2 = a^2 + b^2$
			$\sin \theta = \frac{a}{c}$
			$\cos \theta = \frac{b}{c}$
			$\tan \theta = \frac{a}{b}$
			

ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^8$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol ⁻¹	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m ³ /kg·s ²
Universal gas constant, $R = 8.31$ J/(mol·K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s ²
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	
1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27}$ kg = 931 MeV/c ²
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s = 4.14×10^{-15} eV·s
	$hc = 1.99 \times 10^{-25}$ J·m = 1.24×10^3 eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C ² /N·m ²
Coulomb's law constant, $k = 1/4\pi\epsilon_0 = 9.0 \times 10^9$ N·m ² /C ²	
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant, $k' = \mu_0/4\pi = 1 \times 10^{-7}$ (T·m)/A	
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^5$ N/m ² = 1.0×10^5 Pa

UNIT SYMBOLS	meter, m	mole, mol	watt, W	farad, F
	kilogram, kg	hertz, Hz	coulomb, C	tesla, T
	second, s	newton, N	volt, V	degree Celsius, °C
	ampere, A	pascal, Pa	ohm, Ω	electron volt, eV
	kelvin, K	joule, J	henry, H	

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin \theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos \theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan \theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

- I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- II. In all situations, positive work is defined as work done on a system.
- III. The direction of current is conventional current: the direction in which positive charge would drift.
- IV. Assume all batteries and meters are ideal unless otherwise stated.
- V. Assume edge effects for the electric field of a parallel plate capacitor unless otherwise stated.
- VI. For any isolated electrically charged object, the electric potential is defined as zero at infinite distance from the charged object.

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

MECHANICS		ELECTRICITY AND MAGNETISM	
$v_x = v_{x0} + a_x t$	a = acceleration	$ \vec{F}_E = \frac{1}{4\pi\epsilon_0} \frac{ q_1 q_2 }{r^2}$	A = area
$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$	d = distance	$\vec{E} = \frac{\vec{F}_E}{q}$	B = magnetic field
$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$	E = energy	$ \vec{E} = \frac{1}{4\pi\epsilon_0} \frac{ q }{r^2}$	C = capacitance
$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$	F = force	$\Delta U_E = q\Delta V$	d = distance
$ \vec{F}_f \leq \mu \vec{F}_n $	f = frequency	$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$	E = electric field
$a_c = \frac{v^2}{r}$	h = height	$ \vec{E} = \left \frac{\Delta V}{\Delta r} \right $	$\mathcal{E}$ = emf
$\vec{p} = m\vec{v}$	I = rotational inertia	$\Delta V = \frac{Q}{C}$	F = force
$\Delta \vec{p} = \vec{F} \Delta t$	K = kinetic energy	$C = \kappa\epsilon_0 \frac{A}{d}$	I = current
$K = \frac{1}{2} mv^2$	k = spring constant	$E = \frac{Q}{\epsilon_0 A}$	ℓ = length
$\Delta E = W = F_{\parallel} d = Fd \cos \theta$	L = angular momentum	$U_C = \frac{1}{2} Q\Delta V = \frac{1}{2} C(\Delta V)^2$	P = power
$P = \frac{\Delta E}{\Delta t}$	ℓ = length	$I = \frac{\Delta Q}{\Delta t}$	Q = charge
$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$	m = mass	$R = \frac{\rho \ell}{A}$	q = point charge
$\omega = \omega_0 + \alpha t$	P = power	$P = I \Delta V$	R = resistance
$x = A \cos(\omega t) = A \cos(2\pi f t)$	p = momentum	$I = \frac{\Delta V}{R}$	r = separation
$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$	r = radius or separation	$R_s = \sum_i R_i$	t = time
$\vec{a} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$	T = period	$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$	U = potential (stored) energy
$\tau = r_{\perp} F = rF \sin \theta$	t = time	$C_p = \sum_i C_i$	V = electric potential
$L = I\omega$	U = potential energy	$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	v = speed
$\Delta L = \tau \Delta t$	v = speed	$B = \frac{\mu_0 I}{2\pi r}$	ρ = resistivity
$K = \frac{1}{2} I\omega^2$	W = work done on a system	$\vec{F}_M = q\vec{v} \times \vec{B}$	θ = angle
$ \vec{F}_s = k \vec{x} $	x = position	$ \vec{F}_M = q\vec{v} \sin \theta \vec{B} $	Φ = flux
	α = angular acceleration	$\vec{F}_M = I\vec{\ell} \times \vec{B}$	
	μ = coefficient of friction	$ \vec{F}_M = I\vec{\ell} \sin \theta \vec{B} $	
	θ = angle	$\Phi_B = \vec{B} \cdot \vec{A}$	
	τ = torque	$\Phi_B = \vec{B} \cos \theta \vec{A} $	
	ω = angular speed	$\mathcal{E} = -\frac{\Delta \Phi_B}{\Delta t}$	
		$\mathcal{E} = B\ell v$	
	$U_s = \frac{1}{2} kx^2$		
	$\Delta U_g = mg \Delta y$		
	$T = \frac{2\pi}{\omega} = \frac{1}{f}$		
	$T_s = 2\pi \sqrt{\frac{m}{k}}$		
	$T_p = 2\pi \sqrt{\frac{\ell}{g}}$		
	$ \vec{F}_g = G \frac{m_1 m_2}{r^2}$		
	$\vec{g} = \frac{\vec{F}_g}{m}$		
	$U_G = -\frac{Gm_1 m_2}{r}$		

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AP PHYSICS LAB GUIDE

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AP PHYSICS LAB GUIDE

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*These labs require the teacher or students to construct some electronic apparatus. Teachers with little or no experience with electronics may wish to forego these labs, or to undertake them as extended projects with students.

INTRODUCTION

The AP[®] Physics program has long advocated the inclusion of laboratory work in the syllabus of the Physics B and Physics C courses. One reason for this is that laboratory work can provide additional opportunities for learning, reinforcing, and exploring physical concepts that are discussed in the classroom. A second reason is that most college courses include a laboratory component in the introductory physics course. If AP Physics is to be equivalent to an introductory college course, the AP course should also include a fair amount of lab work. Students should keep a lab notebook, or other kind of lab work portfolio, that indicates the amount and the quality of the lab work that the students perform. This notebook or portfolio has been found to be useful in demonstrating to colleges the nature of the lab work undertaken in the AP course.

How much time ought to be spent on lab work? The College Board has found that lab work counts for approximately 20% of the grade in introductory physics courses, with about one lab experiment being performed each week. Many high school faculty find it difficult to set aside a double period, or two regular class periods, each week to accommodate lab work. If one lab a week is not possible, determine how much time can be spent on lab work without diluting the curriculum. Realize that, both in terms of providing a quality course and preparing the students for the exam, some lab work is necessary, but it is not necessary to have the students perform a lab exercise every week. It is better to have the students perform an exercise in depth, taking time to understand the principles involved and to analyze thoroughly the data which they obtain, than to force-march the students through a series of cookbook-style labs.

The following lab guide was written in order to provide some assistance and advice on setting up a lab component for the AP Physics B and C courses. It is not a sequence of experiments that must be followed. It does not include an array of specialized techniques that must be mastered. It does provide an introduction to data analysis and experimental procedure. There is an emphasis on graphical analysis, with some statistical analysis. The equipment used is often simple. Circuit diagrams and drawings are provided to allow teachers to build, rather than buy, equipment that is unique to some experiments. Computer acquisition and analysis of data is not emphasized, although many experiments may be carried out with computer-based interfaces and sensors. This lab guide is written less for the experienced teacher with decades of work in the classroom, and more for the neophyte teacher who needs some advice on what may be done, often with limited facilities and time, to get lab work into the AP curriculum.

After deciding how to incorporate lab work into the course, a teacher must then decide how much structure to impose on the students' lab work. At one end of the spectrum, the students manipulate lab equipment in a way that is clearly defined in a detailed procedure given to them by the teacher. The results that the students obtain are then checked against the results expected for the experiment. In this approach, the students do little if any work in setting up or designing the experiment. This approach, sometimes derisively referred to as the "cookbook" approach, is the one that is employed in the overwhelming majority of college physics courses. While it may be useful in acquainting students with the operation of equipment with which they are unfamiliar, it is largely ineffective in enhancing student understanding of the physical concepts being studied.

At the other end of the pedagogical spectrum, students engage in open investigations with minimal guidance from the instructor. The students are responsible for the design of the lab exercise, putting together the experimental apparatus, carrying out the experiment, analyzing the data, and extracting a conclusion from their analysis. For highly self-motivated and clever students, this is a wonderful way to do experimental physics. For most students, it turns into an exercise in frustration.

The middle way emphasizes student involvement in the lab by requiring them to do more than follow a tried-and-true recipe in a lockstep manner. Instructors set definite goals for the laboratory exercise, provide some of the procedure, but require students to set up laboratory equipment, or modify lab set-ups used in previous labs or classroom demonstrations. Students determine what data to take, and how to analyze it, in order to accomplish the objectives set by the instructor.

Ideally, we move the students from complete dependence on a lab procedure generated by the teacher to the point where the student can carry out independent investigations. Realistically, what can be expected in the introductory course is to begin to wean the students away from complete dependence to the point where they can perform labs along the lines of the middle way suggested above.

The labs in the AP lab guide may be presented to students in as open-ended a manner as the teacher feels comfortable with. When students first encounter some pieces of equipment, such as a voltmeter or a motion sensor, they require more guidance than they do later in the course, when they have become familiar with various apparatus. This does not mean that the kinematics labs must be done in a cookbook fashion. Many AP students have already had a

course in high school physics before they take the AP course, and have some familiarity with the lab equipment. In those cases, labs early in the term can begin in a more open-ended manner.

For this reason, the AP lab guide does not mandate that experiments be done in a particular manner. The lab write-ups offered in the guide discuss the motivation for and theory behind a particular exercise, describe the procedure for carrying it out, and suggest ways of analyzing the data. **The lab exercises in this AP lab guide are NOT the canonical set of laboratory exercises that must be included in an AP Physics course.** The exercises cover many of the phenomena studied in the Physics B and Physics C courses, but the coverage is not complete. The purpose of the guide is not to present the best 19 introductory physics lab exercises. The purpose is to provide a set of exercises that illustrate the laboratory skills that are central to investigations in physics.

Safety has been a concern in determining which lab exercises to include in the guide. Most of the experiments can be undertaken knowing there is no risk to the students. Some, particularly the optics experiments that use a laser, require the teacher to adopt rigorous safety protocols. Any teacher using a laser, or any piece of equipment that uses line voltage (the 110 VAC that comes out of most wall sockets), should prepare the class for the lab with a presentation on the hazards that the lab equipment presents and the safety procedures to be used in lab. We strongly suggest that teachers take advantage of summer workshops and institutes to become familiar with equipment before using it in the classroom.

One of the questions that all physics teachers face when designing a set of laboratory exercises is the degree to which computers are used to acquire and analyze data. To some the lack of computers can be seen as a bar to doing interesting physics labs. We suggest that while a computer can be an extremely useful tool in the introductory lab, it should not become the focus of the lab activity. The emphasis should be on the physical principles being investigated, not on the manipulation of software. To that end, it is strongly recommended that students graph data by hand in the first few labs before using computer spreadsheets and graphing packages to do the work for them. The reason is that students who use only graphing programs often do not understand what such basic quantities as slope and y-intercept actually mean. The slope of a line becomes simply an answer generated by the program, and not a quantity that expresses the rate of change of one variable with respect to another. Students should be encouraged to use computers to analyze data, even if they don't use computers in the lab to acquire data, but only when their use elucidates rather than obscures the interpretation of data.

Mechanics Labs

The array of possible mechanics experiments can be overwhelming, even for experienced teachers. The mechanics experiments presented here cover one-dimensional kinematics, two-dimensional kinematics, dynamics, rotational motion, and oscillatory motion. Most of these may be done with simple equipment; one does require the use of a computer or calculator-based lab (CBL) system to acquire and analyze data.

The equipment required for most of these labs is cheap, easily transported and stored, and robust. In mechanics, the primary quantities of interest are distance, time, and mass. Each lab setup should have a meter stick or two, a stopwatch, and a set of calibrated masses. If a set of calibrated masses is beyond your budget, you might consider purchasing a few inexpensive balances.

The dynamics lab is presented in two versions, one that uses photogate timers and another that uses motion sensors. Each of the labs has some specialized equipment and materials, but an effort has been made to keep the financial outlay for new equipment small. The need to do labs in AP Physics can serve to acquire additional funds for equipment from budget-conscious administrators, but the emphasis in lab should always be on having as many students as possible participate directly in the lab exercise. It is better to have a large number of simple lab setups than a small number of gee-whiz setups.

Electricity and Magnetism Labs

Labs involving electricity and magnetism may be daunting to the new teacher, but these labs are often easy to set up and run with a minimum of equipment. The availability of cheap and reliable equipment, together with the large array of experiments that may be performed with that equipment, make E&M labs particularly attractive in the introductory course.

The following E&M labs involve two different kinds of electric and magnetic phenomena: those that are constant in time (contained in both Physics B and Physics C syllabus), and those that are time dependent (only in Physics C syllabus). The time-independent, or DC, labs that are described here require a minimum of equipment. The time-dependent labs require the use of more equipment, but allow the students to investigate more phenomena. This trade-off is one to keep in mind as you design your lab syllabus, and as you budget for equipment. Once again, as is the case for mechanics labs, it is better to have a large number of setups so that all students may directly participate in the lab, rather than a few setups that render many students passive spectators.

Each lab setup should have a solderless breadboard, a selection of hookup wires, two multimeters, and a power supply. In addition to hookup wires, the students need test leads with stackable banana plugs, as well as alligator clips that accept banana plugs. Hand tools you need: a wire stripper, needle-nose pliers, and small Phillips and straight blade screwdrivers. Your lab toolbox should also contain a roll of electrician's tape, a roll of duct tape, a soldering pencil, and a roll of thin rosin-core solder.

The hookup wire should be #22 AWG copper wire with plastic insulation. It should be available in at least two colors, and you should cut it to several lengths (2 inch, 4 inch, and 6 inch are useful) before stripping a quarter-inch of the insulation from each end of the wires. The gauge of the wire is important, as larger wire does not fit in the holes in the solderless breadboard, and smaller wires do not make good electrical contact in the holes in the breadboard.

Optics and Modern Physics Labs

The optics and modern physics labs cover material in the B curriculum. The material and equipment used is outlined in the labs, but a special note here concerning laser safety is in order. The lasers used in the introductory labs often have an output power between one and five milliwatts, which make them dangerous. A beam of that power, if it enters the eye directly, can cause severe eye injury. Students must be aware that these devices are not toys, and that misusing them can cause injury to themselves and others. The lab setups should be constricted so that there are beam stops on the lab bench (a book will do) to block the beam from bouncing around the classroom and inadvertently blinding a classmate. All lab setups should be checked to make sure that stray reflections have been minimized and contained. Safety must be emphasized when students work with these small, seemingly innocuous lasers.

The following index provides a guide to the experiments in the lab guide. The title of the experiment is given, and the objectives are listed in terms of the physical concept investigated and the lab technique taught. The labs are generally appropriate for both B and C courses, except for cases where the content is unique to one of the two curriculums.

Lab Exercise	Concept	Lab Skill
Mechanics		
Diluting Gravity 1	One-Dimensional Kinematics	Graphical Analysis Error Analysis
Diluting Gravity 2	One-Dimensional Kinematics	Computer Acquisition and Data Analysis
The Coffee Filter and Air Resistance	One-Dimensional Dynamics	Graphical Analysis
Elastic Collisions	Conservation of Momentum One- and Two-Dimensional Collisions	Error Analysis
The Turning Point	Conservation of Energy Circular Motion	Graphical Analysis Error Analysis
The Whirligig	Circular Motion	Error Analysis
Hooke's Law and Harmonic Motion	Hooke's Law	Graphical Analysis
Electricity and Magnetism (all labs can be used to teach breadboarding techniques)		
Ohm's Law 1	Ohm's Law	Graphical Analysis
Ohm's Law 2	Real vs. Ideal Test Instruments	Graphical Analysis Error Analysis
Electrical Power and Batteries 1	Internal resistance of batteries, Joule heating	Graphical analysis Numerical integration
Electrical Power and Batteries 2	Internal resistance of batteries, Joule heating	Graphical analysis Curve fitting
RC Time Constant 1	RC circuits (only in Physics C syllabus)	Graphical Analysis Error Analysis
RC Time Constant 2	RC circuits (only in Physics C syllabus)	Using an Oscilloscope Graphical Analysis
Magnetic Fields 1	Biot-Savart Law	Graphical Analysis
Magnetic Fields 2	Strength and Direction of the Earth's Field	Error Analysis Vector Algebra
Optics		
Geometrical Optics: Determining the Index of Refraction	Index of refraction of a Rectangular Slab	Error Analysis Statistical Analysis of Error Laser Safety
The Diffraction Grating	Interference	Error Analysis Laser Safety
Modern Physics		
Planck's Constant on the Cheap	Photoelectric Effect with LEDs	Graphical Analysis Error Analysis
The Photoelectric Effect	Photoelectric Effect	Graphical Analysis Error Analysis

LAB ONE**Diluting Gravity: A Computer-Based Laboratory****Introduction**

The kinematics of one-dimensional motion is usually the first material covered in an introductory physics course. When confined to the case of constant acceleration, one-dimensional kinematics provides a subject that is amenable to classroom analysis and laboratory study both in non-calculus and calculus-based courses. The kinematic equations describe the position x and the velocity v of an object in terms of its initial position x_0 , its initial velocity v_0 , the time t , and the object's acceleration a . The two equations used in this lab are

$$x = x_0 + v_0 t + \frac{1}{2} a t^2 \quad (1-1)$$

$$v = v_0 + a t \quad (1-2)$$

If the object of interest is falling freely near Earth's surface, the magnitude of the acceleration is commonly denoted by g , which has a magnitude of 9.8 m/s^2 . In this lab, a local value of g is measured. We dilute g by having the object accelerate down an inclined plane. We reduce the friction that the object experiences by using a glider on an air track as the object. When we raise one end of the air track so that it makes an angle θ with respect to the horizontal, the acceleration down the inclined air track is given by the equation

$$a = g \sin \theta \quad (1-3)$$

If we start the glider from rest, Equations 1-1 and 1-2 may now be written as

$$x = x_0 + \frac{1}{2} (g \sin \theta) t^2 \quad (1-4)$$

$$v = (g \sin \theta) t \quad (1-5)$$

Equipment

Two ways of doing this lab are presented here. Both require an **air track** and **air track glider**. One method uses a **pair of photogates** to measure the time during which the object moves on the track. The other method uses a **sonic ranger** and **computer data acquisition system** to obtain the glider's position as a function of time. If time permits, it is useful to do the lab both ways in order to introduce students to the advantages and disadvantages of computer data acquisition.

Diluting Gravity 1

Experimental Procedure

The students find the factor $\sin \theta$ by taking the ratio of the height H to which they raise one end of the air track to the distance L between the air track supports, as shown in Figure 1.1. An easy and reproducible way to raise the track is to place a metal block under the supports at one end of the air track. A pair of blocks, one 0.5 inch high and one 1.0 inch high, allow the students to obtain data at three different track inclinations. The height of the metal blocks may be

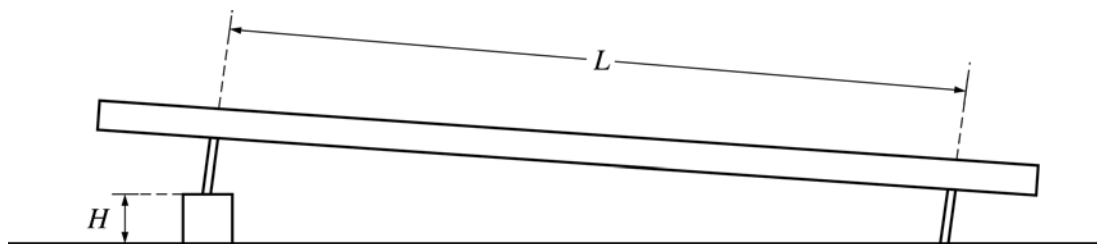


Figure 1.1

measured with a vernier caliper, and the distance between the air track supports with a meter stick. When the students calculate $\sin \theta$, they need to be careful about the number of significant figures they use. For example, suppose the distance L between the supports is 90.5 ± 0.1 cm, and the height H of the metal block is 2.531 ± 0.001 cm. The three significant figures in the measurement of L mean that the calculated value of $\sin \theta$ should have only three significant figures.

The time measurement is taken by the two photogates, which are separated by a distance S . The timer starts when the glider passes through the first gate, and stops when the glider passes through the second. The students vary the photogate separation S , and record the time it takes for the glider to traverse those separations. If the glider is released so that it triggers the first photogate as soon as the glider starts down the ramp, then Equation 1-4 may be written as

$$S = \frac{1}{2}(g \sin \theta)t^2 \quad (1-6)$$

Thus a plot of t^2 versus S should yield a straight line with a slope equal to the reciprocal of $\frac{1}{2}g \sin \theta$. This may be used to calculate a local value of g .

Error Analysis

The two places where problems arise in this lab are the error introduced because the glider is already moving when it triggers the first photogate, and measuring the separation of the photogates. Determining the error associated with measuring the separation of the gates is

straightforward. The error associated with the delayed triggering of the first photogate is a bit more involved. If, after being released, the glider travels a distance R before it triggers the first photogate, it has a nonzero velocity at the beginning of the interval S . Now we need to determine that initial non-zero velocity, to determine the size of the error it introduces.

Rearranging Equations 1-1 and 1-2 to eliminate time, we obtain

$$2a(x - x_0) = v_1^2 - v_0^2 \quad (1-7)$$

Here v_1 is the velocity as the glider reaches the first photogate, the initial velocity v_0 is zero, the acceleration a is equal to $g \sin \theta$, and $(x - x_0)$ is equal to R . The velocity v_1 is then given by

$$v_1^2 = 2gR \sin \theta \quad (1-8)$$

Now assume that we want the error in the value of S to be less than 5% due to the nonzero velocity at the first photogate. Using Equation 1-6:

$$R = (0.05)S = (0.05)\left[\frac{1}{2}g \sin \theta t^2\right]$$

Setting this equal to $v_1 t$ and substituting:

$$(0.05)\left[\frac{1}{2}g \sin \theta t^2\right] = v_1 t \quad (1-9)$$

$$0.025 g \sin \theta t = [2gR \sin \theta]^{1/2}$$

$$R = 0.00031 g \sin \theta t^2$$

For a t value of 4.5 seconds, and $\sin \theta$ equal to 0.1, we obtain R equal to 0.0063 meters, or about one quarter-inch. Students should plug in their own numbers to convince themselves that their results are affected by about this amount. They should compare this error to the effect of the uncertainty in the length measurement noted above in the discussion of significant figures.

Diluting Gravity 2

Experimental Procedure

In the second procedure the student employs a technology called the sonic ranging sensor that has been in use in physics classrooms for two decades. The sonic ranging sensor determines the distance to an object by measuring the time it takes for an ultrasonic pulse to travel from the sensor to the target and back again. Good results are obtained for flat objects that are perpendicular to the direction of propagation of the ultrasonic pulses, as long as these objects are at least 5 cm by 5 cm. This usually means that a small cardboard flag must be mounted on the air track glider to provide a flat target for the sensor beam. The sensors often have a dead

spot, or region where measurements are inaccurate, which extends from the sensor out to a distance of 20 cm.

With these restrictions in mind, using the sensor is straightforward. It is best to mount the sensor at the raised end of the track, so that the glider moves further away with the passage of time. The glider is released, and then the sensor is triggered so that the computer can begin acquiring data. The data appear on the computer monitor, and may be fit to a quadratic equation using the curve-fitting program available with the data acquisition software. The coefficient of the linear term is equal to the velocity of the glider at the beginning of the data acquisition interval. The coefficient of the quadratic term is equal to $(g \sin \theta)/2$. Data are easy to acquire and analyze using this apparatus, and several trials may be run with gliders of different mass to show that the acceleration is independent of the glider's mass.

In addition to curve fitting, data acquisition programs often allow students to differentiate the data, so that the differential of the displacement with respect to time may be displayed. Physics C students should use this feature first to obtain a velocity versus time graph, then acceleration versus time graph. When they obtain these graphs, they see that the velocity versus time graph is not a smooth linear graph with a positive slope, and the acceleration versus time graph is not a constant with respect to time. This leads to a discussion of how the computer processes the data when it differentiates numerically, and the apparent discrepancy that results when compared to the expected graphs of velocity and acceleration versus time. That discussion is useful in showing the students the power and the limitations of their data processing program. They should see that curve fitting, since it is a best fit to all of the data, is a better method of obtaining the glider's acceleration than two successive numerical differentiations. These numerical differentiations can introduce artifacts into the data that can obscure the underlying phenomenon of motion with constant acceleration.

If students begin the lab with the working hypothesis that the glider is undergoing constant acceleration, one test of that hypothesis is to fit the data to a higher order polynomial. Students can use their data processing software to fit their data to a third-degree or higher order polynomial. The coefficients of the terms that are of cubic order or higher should be very small compared to the linear and quadratic terms. If the quadratic term is the highest significant term, this indicates that the object is undergoing constant nonzero acceleration.

LAB TWO**The Coffee Filter and Air Resistance****Introduction**

Students are introduced to the concept of air resistance as a velocity-dependent force early in their study of mechanics. They are often quickly counseled to ignore it, except perhaps for the occasional problem involving the determination of a terminal velocity. If an object of mass M falls under the influence of gravity and a drag force F_{drag} , we may write Newton's Second Law as

$$Ma = Mg - F_{\text{drag}} \quad (2-1)$$

Here a is the acceleration of the object, and Mg is the weight of the object. We may model the drag force F_{drag} as shown in Equation 2-2.

$$F_{\text{drag}} = bv^n \quad (2-2)$$

Here the drag coefficient b is a constant that depends on the shape of the object, and v is the velocity of the object. For objects moving at low velocity through air n is usually close to 2. By substituting Equation 2-2 into Equation 2-1 we obtain:

$$Ma = Mg - bv^n \quad (2-3)$$

As an object falls from rest the velocity increases until the drag force and the weight are equal in magnitude. The acceleration is then zero, and we have

$$Mg = b(v_f)^n \quad (2-4)$$

This may be rearranged to give the terminal velocity v_f :

$$v_f = (Mg/b)^{1/n} \quad (2-5)$$

Now by taking the logarithm of both sides of Equation 2-5 we obtain

$$\ln v_f = (1/n)[\ln M + \ln g - \ln b] \quad (2-6)$$

This may be rewritten as

$$\ln v_f = (1/n)\ln M + C \quad (2-7)$$

where C is a constant equal to $(1/n)[\ln g - \ln b]$.

We can now determine the exponent n of the velocity v if we can determine the terminal velocities v_f for a variety of masses. A log-log plot of the terminal velocity versus the mass then yields a linear plot with a slope of $1/n$.

The problem with varying the masses is that the drag coefficient depends on the size and configuration of the object. This is why we can't do the lab by dropping a ping-pong ball, a golf ball and a bowling ball from the top of the school building. That is where the coffee filters come in. By dropping stacks of coffee filters consisting of one, two, or more filters, we may vary the mass of the falling object while keeping its size and configuration approximately the same.

Experiment

The coffee filters used in this lab are those that look like an inverted crown or a basket. The corrugations of the filter make it easy to nestle them one inside the other. A large vertical drop of a few meters must be used; we suggest at least 3 meters. The best results are acquired by using as large a vertical drop as feasible.

The procedure is straightforward. A student drops the filters, while a second student times their fall. The average velocity v of the filters is found by dividing H , the height of the drop, by T , the time of the fall from release to impact. Several trials (5-10) should be used for each value of the mass, i.e., each number of filters.

In order to find the coefficient n , we then make the assumption that the filters quickly attain their terminal velocity v_f . We then may equate the average velocity given by H/T to the terminal velocity. As the number of filters increases, this approximation becomes worse since it takes a longer time for the larger mass to reach its terminal velocity. It is best if the students perform the experiment with groups of one, two, three, and four filters. Since the filters all have approximately the same mass, this corresponds to multiples of one, two, three, or four units of mass, with the unit of mass being one coffee filter.

The students graph the data on log-log paper, with velocity on the vertical axis and the number of filters on the horizontal axis. The slope of the resulting straight line is equal to $1/n$. The students can also graph the number of filters on the vertical axis and the fall time on horizontal axis, which will give a straight line with a slope of $(-n)$. This is a useful exercise for students who are unsure of their logarithms.

Students should be asked what effect the approximation made by equating the average and terminal velocity has on their answer for n . They should be able to reason that the average velocity is lower than the terminal velocity, and that the values of n they obtain are therefore higher than the expected value of 2.

LAB THREE**Elastic Collisions****Introduction**

Collisions in one and two dimensions provide some of the most common illustrations of the conservation of linear momentum. Elastic collisions allow the student to study both conservation of linear momentum and conservation of energy. Air tracks and frictionless carts are one way of studying these collisions in one dimension. In this lab we describe how to construct a simple inexpensive apparatus for the study of one-dimensional and two-dimensional elastic collisions.

First we review the basic physics involved in elastic collisions in one dimension. We consider an object of mass M_1 moving with an initial velocity v_{1i} that undergoes an elastic collision with an object of mass M_2 moving with a velocity v_{2i} . After the impact, the mass M_1 has a final velocity v_{1f} , and the mass M_2 has a velocity v_{2f} . The general equation for conservation of linear momentum for this system states that

$$M_1 v_{1i} + M_2 v_{2i} = M_1 v_{1f} + M_2 v_{2f} \quad (3-1)$$

where + and – signs are used for a specific case to indicate the direction of each velocity.

When we apply the conservation of energy to this system we find that

$$\frac{1}{2} M_1 v_{1i}^2 + \frac{1}{2} M_2 v_{2i}^2 = \frac{1}{2} M_1 v_{1f}^2 + \frac{1}{2} M_2 v_{2f}^2 \quad (3-2)$$

For the system studied in this lab, the object of mass M_2 is initially at rest. Since v_{2i} is zero, Equations 3-1 and 3-2 become, respectively, Equations 3-3 and 3-4.

$$M_1 v_{1i} = M_1 v_{1f} + M_2 v_{2f} \quad (3-3)$$

$$\frac{1}{2} M_1 v_{1i}^2 = \frac{1}{2} M_1 v_{1f}^2 + \frac{1}{2} M_2 v_{2f}^2 \quad (3-4)$$

We now find the final velocities v_{1f} and v_{2f} in terms of the initial velocity v_{1i} and the masses M_1 and M_2 . To do this we use Equation 3-3 to write v_{1f} in terms of M_1 , M_2 , v_{1i} , and v_{2f} .

$$v_{1f} = v_{1i} - \frac{M_2}{M_1} v_{2f} \quad (3-5)$$

Then we substitute this expression in Equation 3-4 in order to eliminate v_{1f} , and express v_{2f} in terms of M_1 , M_2 , and v_{1i} .

$$\frac{1}{2} M_1 v_{1i}^2 = \frac{1}{2} M_1 \left(v_{1i} - \frac{M_2}{M_1} v_{2f} \right)^2 + \frac{1}{2} M_2 v_{2f}^2 \quad (3-6)$$

After multiplying the squared term and collecting terms we obtain

$$v_{2f} = [2M_1/(M_1 + M_2)]v_{1i} \quad (3-7)$$

If we use Equation 3-7 to eliminate v_{2f} from Equation 3-5 we obtain

$$v_{1i} = [(M_1 - M_2)/(M_1 + M_2)]v_{1i} \quad (3-8)$$

In this lab, for the case of objects of equal mass, Equation 3-7 implies that the second mass moves forward with a velocity equal to v_{1i} . Equation 3-8 implies the velocity of the first mass after the collision is zero.

In two dimensions, the math is a little trickier. We must now conserve momentum in both dimensions, and therefore must write a vector equation for momentum. Assuming that v_{2i} is zero, we have

$$\frac{1}{2}M_1v_{1i}^2 = \frac{1}{2}M_1v_{1f}^2 + \frac{1}{2}M_2v_{2f}^2 \quad (3-9)$$

$$M_1\mathbf{v}_{1i} = M_1\mathbf{v}_{1f} + M_2\mathbf{v}_{2f} \quad (3-10)$$

We now consider the case where M_1 and M_2 are equal. Equations 3-9 and 3-10 then become, respectively,

$$v_{1i}^2 = v_{1f}^2 + v_{2f}^2 \quad (3-11)$$

$$\mathbf{v}_{1i} = \mathbf{v}_{1f} + \mathbf{v}_{2f} \quad (3-12)$$

We square both sides of Equation 3-12 to obtain

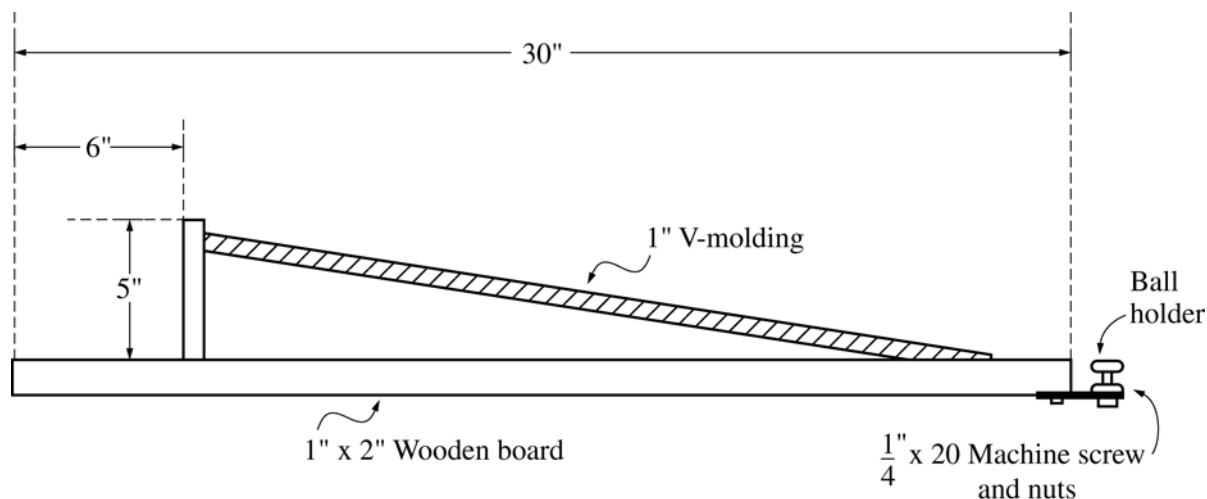
$$v_{1i}^2 = v_{1f}^2 + 2(\mathbf{v}_{1f} \cdot \mathbf{v}_{2f}) + v_{2f}^2 \quad (3-13)$$

A comparison of Equations 3-11 and 3-13 indicates that the dot product of $\mathbf{v}_{1f}$ and $\mathbf{v}_{2f}$ must be zero, which implies that the two vectors are perpendicular.

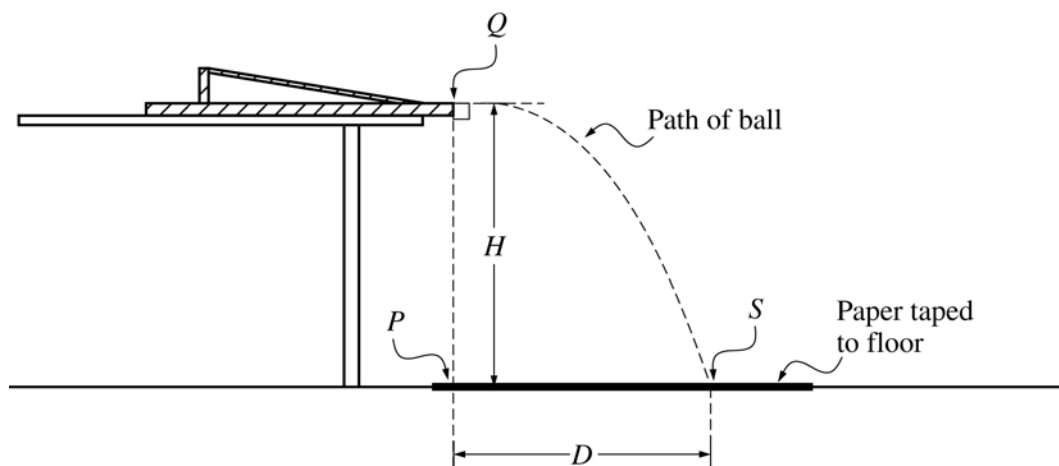
Equipment

The equipment, shown in Figure 3.1, consists of a ramp made from a piece of wooden v-molding, and a wooden support for the ramp. A holder for the target ball is attached at the end of the horizontal support as shown. The holder consists of a strip of metal that is screwed to the underside of the horizontal support, and a machine screw that is used to hold the target ball. The metal strip should not be screwed to the support very tightly, as it needs to be moved during the experiment. A nut holds the machine screw in place, and a second nut is used to hold the target ball.

The ramp support is attached to a lab bench or table with a C-clamp or table clamp so that the target support pokes out over the edge of the bench or table. The first part of the experiment

**Figure 3.1**

consists of rolling a ball down the ramp, with no target on the target ball holder and the holder swung out of the way. The ball leaves the support with a horizontal velocity v , and lands a horizontal distance D away. As shown in Figure 3.2, the distance D is measured from a point P directly beneath the point Q where the ball leaves the ramp, to the point of impact S . The students then cut a piece of paper large enough to extend from the point P to the point S , allowing a border of a few centimeters as well. The piece of paper should be as wide as it is long. The paper is then taped to the floor.

**Figure 3.2**

In order to record the point of impact of the ball, the students place a piece of carbon paper (yes, it is still made) face down on the large piece of paper, with another piece of paper on top of it to prevent the carbon paper from ripping when the ball hits it. The students then roll the ball down the ramp several times, letting the carbon paper mark the impact sites on the large sheet of paper.

For the collision part of the lab, it is useful to think in terms of a horizontal set of x - y axes. The x -axis lies along the direction of travel of the ball as it leaves the ramp. The y -axis is perpendicular to it. A target ball is placed on the ball holder so that the target ball will travel in the x -direction. Another ball of equal mass is rolled down the ramp, striking the target ball. As this collision is elastic, and the masses of the two balls are the same, the momentum of the incident ball is entirely transferred to the target ball. The target ball should land in about the same spot as the impact sites for no collision. The same method, using carbon paper, is used to mark the location of the impacts of the target ball. These marks are then compared to the first set to see if the collision was elastic.

The two-dimensional case is more interesting. The analysis of the results is made easy by the fact that when the two balls collide and move off at non-zero angles with respect to the x -axis, they spend the same amount of time in the air. Both balls drop through the same vertical distance H shown in Figure 3.2. Since both balls have no vertical velocity at the moment of impact, they fall to the ground in the same time t .

Figure 3.3 shows the paths of the two balls as seen from above.

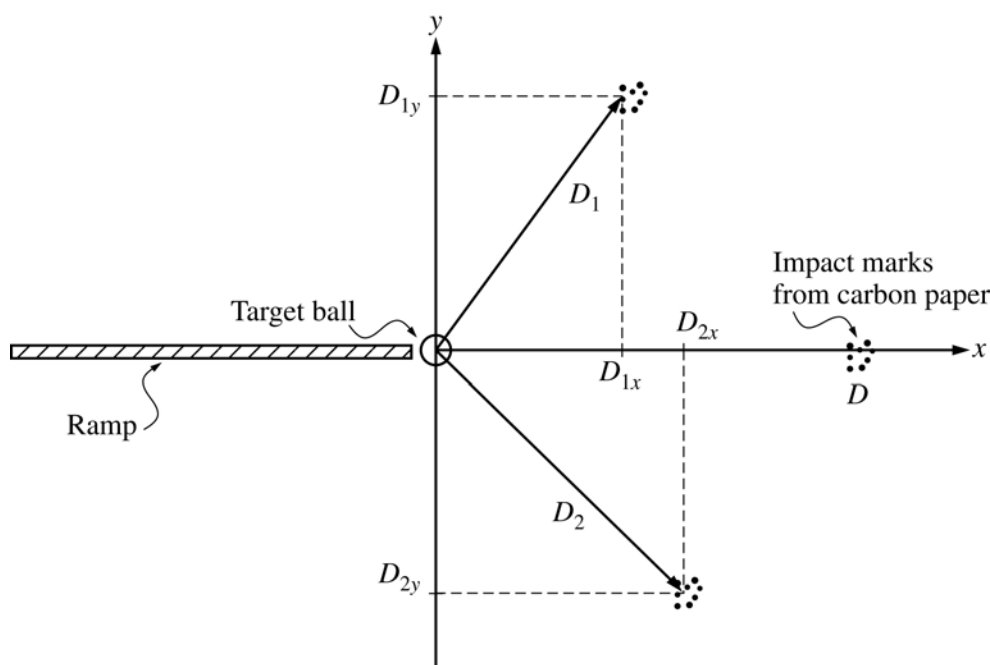


Figure 3.3

Since the horizontal components of the balls' velocities do not change until they hit the ground, the distances D_1 and D_2 are related to the horizontal velocities v_1 and v_2 by

$$D_1 = v_1 t \quad (3-14a)$$

$$D_2 = v_2 t \quad (3-14b)$$

From our earlier measurement of D , we can also determine the initial velocity v as

$$D = vt \quad (3-14c)$$

From conservation of momentum, we know that

$$Mv = Mv_{1x} + Mv_{2x} \quad (3-15a)$$

$$0 = Mv_{1y} + Mv_{2y} \quad (3-15b)$$

Here v_{1x} and v_{2x} are the x -components of v_1 and v_2 , and similarly v_{1y} and v_{2y} are the y -components of v_1 and v_2 . We define D_{1x} and D_{2x} as the x -components of D_1 and D_2 , and D_{1y} and D_{2y} as the y -components of D_1 and D_2 . Substituting Equations 3-14a, 3-14b, and 3-14c into Equations 3-15a and 3-15b yields the following two equations.

$$\frac{D}{t} = \frac{D_{1x}}{t} + \frac{D_{2x}}{t} \quad (3-16a)$$

$$0 = \frac{D_{1y}}{t} + \frac{D_{2y}}{t} \quad (3-16b)$$

Canceling the factor of t yields

$$D = D_{1x} + D_{2x} \quad (3-17a)$$

$$0 = D_{1y} + D_{2y} \quad (3-17b)$$

The experiment is straightforward. The target holder is set so that the two balls go off at non-zero angles with respect to the x -axis after the collision. A ball is placed on the target holder. The other ball rolls down the ramp and collides with the target ball. The ball impacts are recorded using two pieces of carbon paper. Several trials are then run with the target holder in the same position. After a suitable number of collisions are run, the target holder is then repositioned, and another set of collisions are run at the new target holder position. Two sets of data are sufficient, but more can be collected.

The students then determine the centers of the sets of impacts that they obtain, and see if the distances D_{1x} , D_{2x} , D_{1y} , D_{2y} , and D agree with the predictions of Equations 3-17a and 3-17b. The students should attempt to determine what the errors associated with their data are, and incorporate those errors into their determination of the agreement of their data with the predicted results. The scatter of impact marks on the sheet results in an uncertainty associated with the x and y measurements. When adding the x - and y - components of D_1 and D_2 , the students should be sure to carry these uncertainties along in their calculations.

LAB FOUR

The Turning Point

Introduction

The Turning Point is based on a problem commonly encountered in homework sets in the Physics B and Physics C courses. The situation is pictured in Figure 4.1. A pendulum is held out

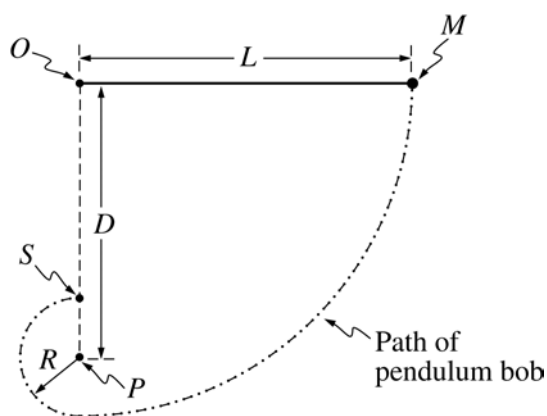


Figure 4.1

so that the pendulum's string is parallel to the ground. The pendulum bob is released, and it describes a circular arc of length L as it descends. When the bob passes through its lowest point, the pendulum string encounters a peg P located a distance D below the pivot point O of the pendulum. The bob continues its motion, but in an arc of reduced radius R . The bob follows a circular arc, passing above the peg P at a point S . The problem, as usually formulated, is to find the minimum distance D for which the string will remain taut as the bob passes through S .

Applying Newton's Second Law, the condition on the string as the bob passes through S may be represented by Equation 4-1.

$$Ma = T + Mg \quad (4-1)$$

Here M is the mass of the bob, T the tension in the string, a the acceleration of the bob, and g the acceleration due to gravity. Since the bob is undergoing circular motion as it passes through S , we have Equation 4-2.

$$a = v^2/R \quad (4-2)$$

Here v is the velocity at point S , and R is the radius through which the bob is moving. At the minimum distance D , the tension T goes to zero, so we may substitute Equation 4-2 into Equation 4-1 to obtain

$$Mv^2/R = Mg$$

This simplifies to Equation 4-3.

$$v^2 = Rg \quad (4-3)$$

Therefore we can find R , and thus D , if we know v . Upon examining Figure 4.1 we see that we may apply conservation of energy at point S to determine v . If we take the zero of gravitational potential energy as the lowest point of the bob's path, we may write Equation 4-4

$$MgL = Mg(2R) + Mv^2/2 \quad (4-4)$$

Substituting Equation 4-3 into Equation 4-4 yields

$$MgL = 2RMg + MRg/2$$

This simplifies to

$$R = 2L/5$$

Examination of Figure 4.1 also shows that the distance D is the difference between L and R , so we have Equation 4-5.

$$D = 3L/5 \quad (4-5)$$

Procedure

The equipment for the lab consists of a **ring stand** or **long rod** about a meter in length, **two right-angle clamps**, **two short rods**, **string**, and a **mass** such as a **rubber stopper** or **lead weight**. If you use a long rod as the vertical support for the apparatus, you should fasten it to the table with a **table clamp** for stability.

The lab set-up is straightforward. Fix the vertical rod to the table with a clamp or set the ring stand up on the table. At the top of the vertical rod, attach one short rod using a right-angle clamp. Attach the other short rod to the vertical rod about halfway up the vertical rod. This second rod is the pivot rod that the pendulum string strikes as the bob moves through its arc. The apparatus is shown in Figure 4.2.

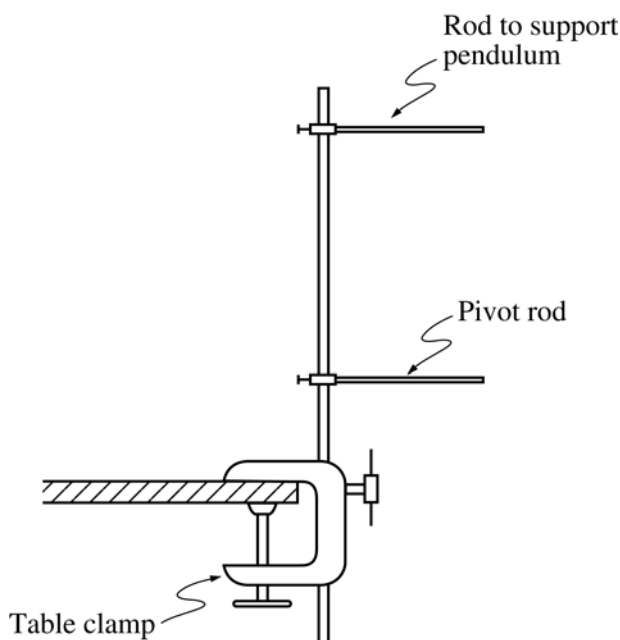


Figure 4.2

Care must be taken in attaching the string to the support rod. The string should not stretch much and should be easily tied (monofilament fishing line works well). It is best to drill a hole close to the end of the rod through which the string may be passed, rather than attempting to tie the string around the support rod. This prevents the movement of the point of attachment of the string while the bob is in motion. It also makes it easier to change the length of the string, so that data may be taken at different values of L . (Special pendulum clamps designed for lab experiments are also available commercially.)

There are several ways to do the experiment. One is to have the students calculate the highest position at which the lower rod must be placed so that the bob rotates about the lower rod while keeping the supporting string taut. They place the lower rod at the distance, release the bob from a horizontal position as indicated in Figure 4.1, and see if the bob describes the desired path. If the bob does not, the students adjust the position of the lower rod to obtain the desired path. Even if the bob does follow the desired path, the students should move the lower rod to convince themselves that they have found the *minimum* distance D for which that path occurs.

A more systematic approach is to start with the lower rod at a distance of $0.75 L$ below the upper rod, then decrease D in small increments until the bob revolves around the lower rod with the string taut. The amount by which D is decreased should be a few millimeters for each trial. One question that the students should answer before they start their measurements and trials is how to measure the distance D . Should they measure to the middle of the lower rod, to its bottom, or to its top? Which measured distance more accurately represents the distance used in the derivation?

If there is enough time, students should repeat the experiment for a range of values of L , preferably from 0.4 meters to 0.9 meters, to generate a table of L and D values. If D is plotted versus L , the data should fall on a straight line with a slope of 0.6. This procedure eliminates some systematic errors that may be present in students' procedure. For instance, if L or D is measured in such a way that the measurements are always too short or too long compared to their actual values, the graph will eliminate those systematic errors, as it depends on the rate of change of D with L . Students should compare the value of the slope of the D versus L plot with the values they obtain for the ratio of L and D for each trial. If the slope is close to the expected 0.6 value, while the ratios are not, this indicates that the students have a systematic error in their data. The students should address this discrepancy in their write-up of the experiment.

LAB FIVE

The Whirligig

Introduction

In this lab the students investigate circular motion in the horizontal plane using an object attached to a string, as shown in Figure 5.1. The forces acting on the object are also shown in

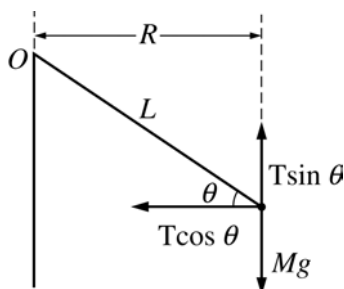


Figure 5.1

Figure 5.1. If the motion is in the horizontal plane, then the vertical component of the tension T and the force of gravity must cancel. In the horizontal plane, the horizontal component of the tension must equal the centripetal force acting on the object. This may be written as Equation 5-1.

$$T \cos \theta = Mv^2/R \quad (5-1)$$

Here v is the speed of the object, and R is the radius of the circle through which it moves. If the string that attaches the object to the pivot point O is of length L , then R may be written as Equation 5-2.

$$R = L \cos \theta \quad (5-2)$$

If the object revolves with a period t , then the object's velocity may be written as Equation 5-3.

$$v = 2\pi R/t \quad (5-3)$$

Substituting Equation 5-3 into Equation 5-1 yields

$$T \cos \theta = 4\pi^2 MR/t^2 \quad (5-4)$$

Substituting Equation 5-2 into Equation 5-4 yields

$$T \cos \theta = 4\pi^2 ML \cos \theta / t^2 \quad (5-5)$$

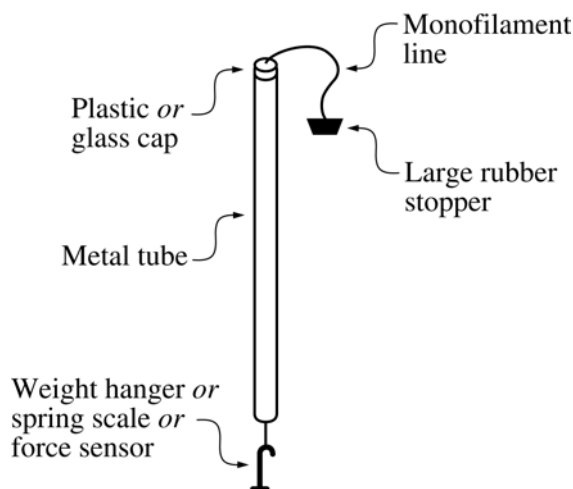
This simplifies to Equation 5-6,

$$T = 4\pi^2 ML/t^2 \quad (5-6)$$

In this lab the students measure T with a force sensor or spring scale, and compare it to the value of T calculated using Equation 5-4.

Procedure

The experiment requires a specialized piece of apparatus that may be constructed or purchased. The apparatus consists of a long thin metal tube, about a meter in length. The mass consists of a large, somewhat soft object, such as a rubber stopper. Use of a deep-sea fishing sinker, or other hard object, is strongly discouraged for safety reasons. The string or monofilament line is attached to the object and then run through the tube. A force sensor, spring scale, or weight hanger to which various numbers of weights are added, is then attached to the string at the bottom of the tube as shown in Figure 5.2.

**Figure 5.2**

If you decide to make this apparatus, it is a good idea to put a small Teflon or glass cap at the top end of the tube, in order to reduce friction between the string and the tube. It is also a good idea to remove any sharp edges on the glass or plastic caps; otherwise the whirling mass will make an unscheduled, unexpected, and often unpleasant transition from circular motion to two-dimensional projectile motion.

This experiment can easily take the full attention of three students. This is a good thing, as it means fewer pieces of the apparatus are operating in the lab room than if the students

worked in two-student teams. One student should operate the whirlingig. The second student should monitor the force sensor, spring scale, or weight hanger. The third student times the rotation of the object. The most difficult part of the lab is whirling the object in such a manner that it undergoes uniform circular motion.

The procedure for performing the experiment is straightforward. The mass M of the object is measured. A length L is selected, and the apparatus adjusted to obtain that value. The whirlingig operator sets the object in motion, maintaining as constant a value of the tension T as possible. Once the student monitoring the force is satisfied with the value and stability of the tension, the time may be determined. The third student, using a stopwatch, measures the elapsed time for a set number of revolutions of the object around the pole. For convenience, this set number is often 10 or 20. The period t is then found by dividing the entire elapsed time for those revolutions by the number of revolutions.

As an example, let's take a 0.150 kg object attached to the string, where L is 0.80 meters. A student whirls it so that the tension reading is 4.1 newtons. The timer records an elapsed time of 10.98 seconds for 10 revolutions. The calculated tension is given by

$$\begin{aligned} T_{\text{calc}} &= 4\pi^2 (0.150 \text{ kg})(0.80 \text{ m}) / (1.098 \text{ s})^2 \\ &= 3.93 \text{ newtons} \end{aligned}$$

Clearly 4.1 newtons, the measured value of T , disagrees with 3.93 newtons, the calculated value of T . At this point the question of significant figures and experimental error arises.

The disagreement E between the calculated tension T_{calc} and the measured tension T_{meas} is given by

$$E = (T_{\text{meas}} - T_{\text{calc}}) / T_{\text{meas}}$$

In this case, we find E to be

$$\begin{aligned} E &= (4.1 \text{ s} - 3.9 \text{ s})/4.1 \text{ s} \\ &= 0.04 \text{ or } 4\% \end{aligned}$$

If we examine the sources of error in the measured quantities, we may associate errors with the measurement of length, mass, and time. The length measurement should be accurate to within 1 or 2 millimeters. The relative error E_{length} associated with the length is then

$$\begin{aligned} E_{\text{length}} &= \Delta L/L \\ &= 0.002 \text{ m}/0.800 \text{ m} \\ &= 0.0025 \text{ or } 0.25\% \end{aligned}$$

The mass measurement should be accurate to within a gram. The relative error E_{mass} associated with the mass is then

$$\begin{aligned} E_{\text{mass}} &= \Delta M/M \\ &= 0.001 \text{ kg}/0.150 \text{ kg} \\ &= 0.0067 \text{ or } 0.67\% \end{aligned}$$

The error associated with the time is the trickiest to determine. If the absolute error associated with the time was plus or minus one unit of the smallest measured division of time measured with the stopwatch, the absolute error in this case would be 0.01 seconds for the 10 revolutions. A better estimate may be obtained by having all of the lab groups simultaneously measure the time it takes for 10 revolutions of a single apparatus. The groups then write down their times, and take one-half of the difference between the lowest and highest times as the absolute error associated with the time measurement. Suppose that in this lab, with four lab groups, the following times were recorded.

Group Number	Time (seconds)	t (seconds)
1	10.98	1.098
2	10.74	1.074
3	11.42	1.142
4	11.02	1.102

The absolute error Δt is then given by

$$\begin{aligned} \Delta t &= (1.142 \text{ s} - 1.074 \text{ s})/2 \\ &= 0.034 \text{ s} \end{aligned}$$

The relative error E_{time} is given by

$$\begin{aligned} E_{\text{time}} &= 2 \Delta t/t \\ &= 2(0.034 \text{ s})/1.098 \text{ s} \\ &= 0.06 \text{ or } 6\% \end{aligned}$$

The factor of two occurs since the time appears as a squared quantity in the equation for the tension. If we add the errors together to obtain the total error E_{total} :

$$\begin{aligned} E_{\text{total}} &= E_{\text{mass}} + E_{\text{length}} + E_{\text{time}} \\ &= 0.25\% + 0.67\% + 6\% \\ &= 7\% \end{aligned}$$

If we treat these independent errors more properly, and add them quadratically, we have

$$\begin{aligned} E_{\text{total}} &= \left[E_{\text{mass}}^2 + E_{\text{length}}^2 + E_{\text{time}}^2 \right]^{1/2} \\ &= 6\% \end{aligned}$$

In either case, the calculated value for the tension and the measured value for the tension do agree to within the experimental error.

Data may also be acquired by making several measurements of the period of revolution at different values of the tension. The student then plots the measured tensions T versus the reciprocal of the square of the time in order to obtain a linear plot (see Equation 5-4). The slope of the line should be equal to the quantity $4\pi^2 ML$. Either method provides the students with experience in error analysis, and can be chosen on the basis of the time available for the lab.

LAB SIX**Hooke's Law and Harmonic Motion****Introduction**

Robert Hooke, nemesis of Isaac Newton, noted that the force necessary to extend an elastic object is proportional to the distance the object is stretched. The force exerted by the object when stretched is opposite to its extension, giving us the vector equation

$$\mathbf{F} = -k\mathbf{x} \quad (6-1)$$

where k is the elastic constant, which for a spring is typically called the spring constant. Now suppose that an object of M is attached to a spring of spring constant k . Further suppose that the spring is extended or compressed and then released. From Newton's Second Law we have the following equation of motion for the object.

$$M(d^2x/dt^2) = -kx \quad (6-2)$$

This may be rearranged to yield Equation 6-3.

$$(d^2x/dt^2) = -(k/M)x \quad (6-3)$$

Equation 6-3 is of the form

$$(d^2x/dt^2) = -\omega^2x \quad (6-4)$$

where ω is the angular frequency of oscillation, and is related to the frequency of oscillation f by Equation 6-5.

$$\omega = 2\pi f \quad (6-5)$$

Equation 6-4 describes any kind of simple harmonic motion. The solutions to Equation 6-4 are of the form given in Equation 6-6

$$x(t) = A\sin(\omega t + \phi) \quad (6-6)$$

where A is the amplitude of the oscillation, t is the time, and ϕ is the phase angle.

Using the fact that the period of oscillation T is the reciprocal of the frequency, we may use Equations 6-3, 6-4, and 6-5 to obtain the following relation between the period of oscillation, the spring constant k , and the oscillating mass M .

$$T = 2\pi(M/K)^{1/2} \quad (6-7)$$

This is the relation that the student verifies in this lab.

In order to do the lab, the student needs to know the value of the spring constant. A straightforward way of doing this consists of adding a weight to the end of the spring and seeing how far it stretches. If the spring stretches a distance L when a mass M is attached to it then from Equation 6-1 we have

$$Mg = kL \quad (6-8)$$

The spring is stretched with a variety of masses, and the extensions L measured for each value of the stretching masses M . A graph of L versus M then yields a straight line with a slope equal to g/k . The spring constant may then be calculated from the slope.

Equipment

Each lab setup should consist of a **meter stick**, a set of **calibrated masses**, a **spring**, a **stopwatch**, and a **support** for the spring. The support can be as simple as a dowel or rod that hangs over the edge of a table. Be sure to tape or otherwise fix the support in place before doing the lab.

Procedure

The lab proceeds in three steps. First, the students determine the spring constant k by hanging various masses from the spring at rest and measuring the extension of the spring. Second, the students determine the spring constant k by hanging a variety of masses from the spring and setting them in motion. By plotting the period T against the square root of the masses, the spring constant k may be determined from the slope of the resulting straight line. In the third part, the two values of k are compared, and any discrepancies resolved.

In the first part of the lab, the unstretched length of the spring is recorded. A mass is added to the spring, and the new spring length is recorded. The extension of the spring is the absolute value of the difference between these readings. The students continue by adding masses to the spring, and determining the spring's extension. The students must always calculate the extension of the spring with reference to the unstretched length.

As the students measure the lengths and masses, they should also make note of the experimental error introduced into their measurements. If the marks on the meter stick are one millimeter apart, then the error involved in each measurement is uncertain by half a millimeter, and the error involved in the extension is twice that. Thus an extension of 25 millimeters should be reported as 0.025 ± 0.001 meters. Wherever possible, students should render all measurements in SI units. When the students graph the extension versus the masses, they should indicate this uncertainty in the form of an error bar on the data point.

The error involved in the mass measurements is more difficult. If the students use a balance, then the error may be assumed to be equal to plus or minus 1 of the last significant digit measured by the balance. Thus if the balance read 54 grams, the mass would be reported as 0.054 ± 0.001 kilograms.

As the students collect data for their graphs, they will ask how many data points they must take. Rather than giving them a number, ask them to think about how many values they think they will need for their graphs, and what values they will need. Ask them if it is better to take

measurements at 1-gram increments from 10 to 20 grams, or fewer measurements, e.g., 20-gram increments from 20 grams to 100 grams. Which set of measurements is more useful, and why? This will get the students thinking about interpolation and extrapolation of data, and begin to get them beyond simply “cookbooking” the lab.

Once the students have their data, they should plot the data by hand to obtain their extension versus mass graphs. The students should then obtain the slope of the linear plot they have, and extract the value of the spring constant from the slope using Equation 6-8. One mistake that students commonly make is to use a single point on the graph, rather than actually calculating the slope of the best-fit straight line via dividing its rise by its run.

Students then proceed to the second part of the lab, where they determine the spring constant k by setting a mass in oscillation and timing its period of oscillation. Students should attach a mass to the spring, then extend the spring a short distance vertically. The amplitude of motion should be small enough that the spring does not become slack as it oscillates. A common mistake in timing the oscillations is to count a full cycle of oscillation every time the mass passes through its equilibrium point. Students do better if they count full cycles of oscillation when the mass reaches one end point of its trajectory, at the maximum extension or compression of the spring. Students should time several full cycles rather than attempting to time just one cycle. They should be able to explain why this procedure reduces the error involved in determining the period of oscillation.

Students should determine the period of oscillation for several values of mass, for example, 0.050 kg, 0.070 kg, 0.100 kg, 0.0150 kg, and 0.200 kg. The masses should be different enough so that a difference in the period is readily apparent. Students should then graph the period versus the square root of the mass in order to obtain a linear plot. The slope of this line may then be determined, and the spring constant obtained using Equation 6-7.

There should be a discrepancy between the two spring constant values. This results from not taking into account the mass of the spring itself. The correction for the mass values used in the second part of the lab consists of adding one third of the spring’s mass to the attached masses. The effective mass, M_{eff} , is given by

$$M_{\text{eff}} = M + (M_{\text{spring}}/3) \quad (6-9)$$

The derivation of this correction term is often omitted in textbooks, and since it uses calculus it is only appropriate for the Physics C course. The kinetic energy of the spring may be written as the integral over the infinitesimal mass elements dm from zero to the spring’s full length L :

$$K_{\text{spring}} = (1/2) \int (dx/dt)^2 dm \quad (6-10)$$

Now the ratio of the velocity v of the mass attached to the spring to the velocity (dx/dt) of the mass element dm located at x is given by

$$v/L = (dx/dt)/x \quad (6-11)$$

The mass density ρ is given by

$$\rho = dm/dx \quad (6-12)$$

or, in terms of the mass of the spring M_{spring} and the length L

$$\rho = M_{\text{spring}}/L \quad (6-13)$$

Substituting Equations 6-11, 6-12, and 6-13 into Equation 6-10 yields

$$K_{\text{spring}} = \frac{1}{2} \int \frac{M_{\text{spring}} v^2 x^2}{L^3} dx \quad (6-14)$$

Integrating x from zero to L yields

$$K_{\text{spring}} = \frac{1}{2} \frac{M_{\text{spring}} v^2}{L^3} \frac{L^3}{3} \quad (6-15)$$

This may be written as

$$K_{\text{spring}} = \frac{1}{2} \frac{M_{\text{spring}}}{3} v^2 \quad (6-16)$$

Thus the kinetic energy of the spring plus the mass M may be written as

$$K = \frac{1}{2} \left(M + \frac{M_{\text{spring}}}{3} \right) v^2 \quad (6-17)$$

An extension of this lab consists of doing a log-log plot of the data in order to determine the exponent in Equation 6-7. Students may take the same number of points, or more to extend the range of the data, and plot the logarithm of the period versus the logarithm of the mass. Taking the log of both sides of Equation 6-7 yields

$$\log T = \frac{1}{2} \log M - \frac{1}{2} \log k + \log(2\pi) \quad (6-18)$$

Thus a plot of $\log T$ versus $\log M$ should give a straight line with a slope of $1/2$. Students may do this plot using a spreadsheet program, or using a sheet of log-log graph paper. If the students have not done a log-log graph before, it is better to have them do this by hand and calculate the slope from the graph. Too many students who rely entirely on software to do all of their graphical analysis do not understand how to calculate a slope from a log-log graph.

The students then have a value of the spring constant k from the method described in the first part of the lab, and they know that the period is proportional to the square root of the mass. What

they don't know is that the period is proportional to the reciprocal of the square root of the spring constant. Ask the students if they can think of a way to show this experimentally.

Another extension of the lab involves demonstrating that the period of oscillation is independent of the amplitude of oscillation. One way of verifying this is to have students perform the determination of the period of oscillation at a variety of amplitudes. A better check is to assign each lab pair or team a different amplitude to check, then have them perform that measurement at each of the lab setups. After all lab pairs or teams have rotated through all of the setups, the results can be tabulated and discussed. This should lead to a discussion of systematic errors in measurements, for some of the lab groups will be consistently lower or higher than everyone else as a result of flaws in their procedures.

LAB SEVEN

Ohm's Law

Introduction

The laboratory exercises in this section study Ohm's Law, which states that the voltage drop V across an electrical component of resistance R that has a current I through it is given by $V = IR$. In this lab the student varies the current I through a resistor R , and measures the resulting changes in the voltage drop V across the resistor. The advantages to this exercise is that data are easy to acquire, and once acquired, a graph of the data result in a linear plot that is easy to interpret.

Ohm's Law 1

Procedure

The lab setup is straightforward. The power supply may be as fancy as a variable-voltage variable-current supply, or as simple as a D cell in a battery holder. The internal resistance, or output impedance, of the power supply is assumed to be negligible in this lab, compared to the other resistances in the circuit.

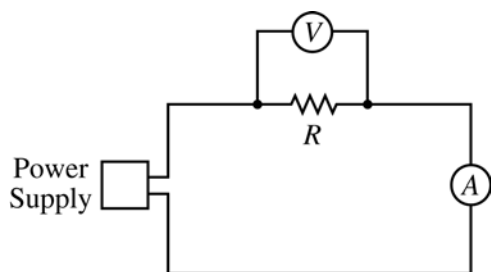


Figure 7.1

If the power supply has a variable output, the circuit is as simple as that shown in Figure 7.1. Varying the current through the resistor could be as simple as turning a knob on the front panel of the power supply. However, we suggest that the variable output feature of the power supply not be used in this lab, in order that the operation of the circuit is as transparent as possible to the students.

The current can be varied by setting up the circuit shown in Figure 7.2. There are two resistors in the circuit, R_1 and R_2 , where R_1 is the resistor under study. By changing the value of R_2 , the current that flows through R_1 is varied.

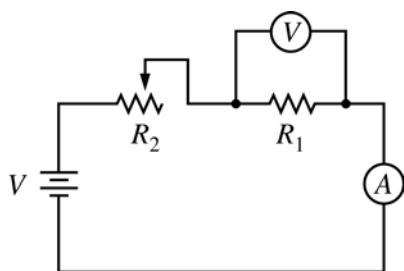


Figure 7.2

There are two ways to vary R_2 . One is to use a variable resistor, or potentiometer, often called a pot. If you choose this option, solder one wire to the wiper, or middle terminal of the pot. Solder another wire to one of the two remaining terminals. If you set a multimeter to the ohmmeter scale and attach the multimeter to the pot before the pot is inserted in the circuit, the students can then see that the resistance of the pot does vary as the shaft is turned.

The resistance of the pot should be an order of magnitude larger than the resistor that you plan to use for R_1 . For example, if R_1 is a 1 kilohm (1 k) resistor, then the pot should have a value of 10 kilohms (10 k). This value refers to the maximum value of the pot's resistance, and is usually marked on the rear of the pot's case.

The second method of varying R_2 is to use a set of resistors. For a 1 k value of R_1 , a set of six R_2 values that give you fairly evenly spaced values of current and voltage are 0.0 (a wire), 470 ohms, 1 k, 2.2 k, 4.7 k, and 10 k. It can be useful to have the students work out the expected voltage and current values before they actually do the lab.

Before starting, students should make a data table in which they enter the values of current and voltage that are obtained. Students should wire the circuit up themselves. It is often useful, particularly when students work with the solderless breadboards for the first time, for them to have a working example in the lab room against which to check their work. As the students wire up their circuits, ask them to not make a complete circuit with the battery or to turn on the multimeters until you check their work. Once you are assured that their connections are correct, have them complete their circuits and turn on the multimeters.

The multimeters should always be set on the lowest sensitivity, or highest full-scale voltage setting, before they are turned on. The meter sensitivity may then be increased, one scale at a time, until the meter reads the maximum number of significant figures. While most multimeters have an automatic overload indicator, this practice of starting the experiment with the equipment at low sensitivity is an important one to teach, as it can prevent the destruction of sensitive equipment in other contexts.

Once the students acquire the data, they should graph it on linear graph paper and determine the resistance of R_1 from the slope of the best-fit straight line. The value that they obtain is then compared to the value of R_1 as measured by a multimeter in the ohmmeter mode. To measure R_1 , break the circuit by disconnecting one of the power supply leads, and switch the multimeter that was being used as a voltmeter to its ohmmeter mode.

Ohm's Law 2

Procedure

This experiment is an extension of Ohm's Law 1, in which the internal resistances, or input impedances, of the voltmeter and ammeter are explored. The idealizations of an ammeter as having zero internal resistance and of a voltmeter as having an infinite internal resistance are often useful. These assumptions simplify the description of the behavior of circuits into which these two pieces of test equipment are inserted. The careful experimentalist remembers that

these are assumptions, and is aware of the restrictions that the equipment used in an experiment imposes.

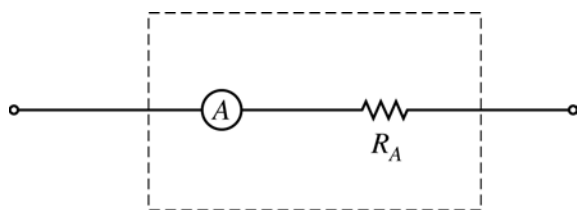


Figure 7.3

A real ammeter can be represented as an ideal ammeter in series with a small resistor R_A as shown in Figure 7.3. The ideal ammeter measures the current flowing through it while offering no resistance to that current. The resistor R_A represents the small but finite resistance with which any real ammeter

opposes the flow of that current. This resistance is on the order of a fraction of an ohm, so that it may be ignored in many applications.

In order to measure R_A , we need to be able to measure resistances on the order of an ohm. One way to do this is shown in Figure 7.4. Resistor R_1 is a $100\ \Omega$ resistor that limits the current

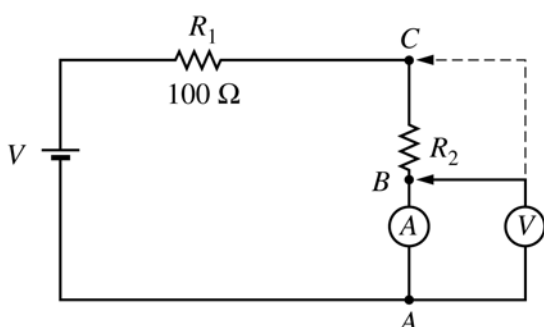


Figure 7.4

through the circuit. Resistor R_2 represents one of a set of resistors whose values run from $0.47\ \Omega$ to $10.0\ \Omega$. In this first exercise, students should use the voltmeter to measure the voltage drop across points AB and across points AC . A suggested approach is to calculate the value of the ammeter resistance R_A for five values of R_2 , such as $0.47\ \Omega$, $1.0\ \Omega$, $2.2\ \Omega$, $4.7\ \Omega$, and $10\ \Omega$. Students should comment on the resulting values for R_A that they

calculate, and discuss which they believe to be most accurate and why.

The second part of the exercise involves studying the internal resistance of the voltmeter. Most digital multimeters have an internal resistance of a couple of megohms. If you are using

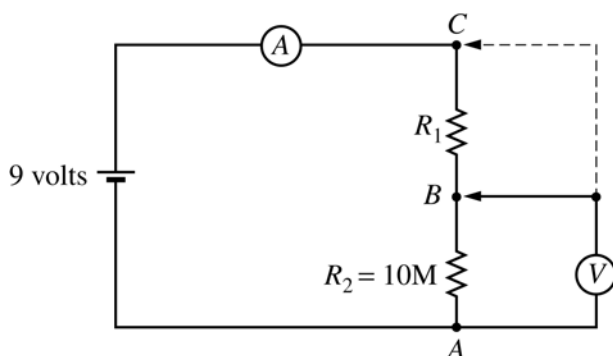


Figure 7.5

old VOMs (**v**olt-**o**hm-**m**eters) in your lab, please be aware that their internal resistance is on the order of tens of kilohms.

For this lab a 9-volt battery is a good choice for a power source, because you use little current in the lab. The circuit shown in Figure 7.5 allows the student to investigate the internal resistance R_V of the voltmeter, where R_1 is a resistor that varies

from 2.0 to 20 megohms. Among the values of R_1 that are the easiest to assemble are 2.0 M Ω , 3.3 M Ω , 5.0 M Ω , 10 M Ω , 15 M Ω , and 20 M Ω . We suggest that students be asked to construct these resistors from 10 M Ω resistors, using the appropriate combinations in series and parallel. The student measures the voltage across AB and AC , and the current through the ammeter for those two voltage measurements (should the current be the same for the two measurements?), and uses the measured values of current and voltage to determine R_V , the internal resistance of the voltmeter. Once again, the student should be asked which value of R_V is most accurate, and why.

LAB EIGHT

Electrical Power and Batteries

Experiment 1

Electrical power is an easy concept for students to master, particularly as it applies to DC circuits. Students learn early on that the power P dissipated in a circuit element is given by

$$P = IV \quad (8-1)$$

Here I is the current through the circuit element, and V is the voltage drop across it. When Equation 8-1 is combined with Ohm's Law, either the current or voltage can be eliminated from the equation to obtain

$$P = I^2 R \quad (8-2)$$

$$P = V^2 / R \quad (8-3)$$

where R is the resistance of the circuit element.

The battery, though ubiquitous, is more difficult to understand. All students know that batteries run down, but see little explanation of this common and annoying fact in their physics courses. Most students are familiar with the concept that the battery has an internal resistance. This resistance limits the output current available from the battery, and can model the drop in the battery's output voltage with increasing current.

What this model doesn't do is explain why the battery runs down. In this lab the student models the behavior of the battery, without attempting to develop an explanation based on the chemistry of the battery. Modeling is often a useful first step in understanding physical processes. Modeling the battery involves coming up with a reasonably accurate equation that can predict the behavior of the battery as a function of load and time.

In this lab the student drains a small battery (AAA) with a large load so that the battery runs down appreciably in the course of an hour. The circuit is straightforward, and is shown in Figure 8.1. The load resistor R is a small resistor in the range from 4.7 to 10 Ω . It is a good idea to have a variety of power ratings available for each value of R that the students use, so that they must calculate the resistor power rating that is adequate for the experiment. The students should be able to use Equations 8-1 to 8-3 listed above to see why using a 1/4 watt, 4.7 Ω resistor with a 1.5 volt battery is not a good idea.

The battery is placed in a small **AAA battery holder**. The **voltmeter** in Figure 8.1 measures the voltage drop across the **ammeter** and the **load resistor R** . The student should be able to explain why the current through the voltmeter may be ignored in the calculation of the power output of the battery. The circuit should not be closed until the instructor checks all the connections, and the students are ready to proceed. The circuit may be kept open either by

leaving one of the leads from the battery holder unconnected, leaving the battery out of the

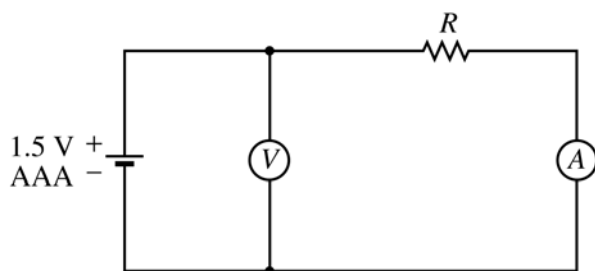


Figure 8.1

holder, or inserting a small switch in the circuit between the voltmeter and the battery.

Once the students are ready to take data, they complete the circuit and read the voltmeter and ammeter simultaneously at fixed time intervals. Taking the data at intervals of one or two minutes for 45 minutes to an hour generates enough data for the lab. Data acquisition can be done by computer, but this is a lab where there is

enough for three members of a lab group to do. The meters will not record steady or steadily decreasing values. The values displayed by the meters are generally decreasing, but there are fluctuations in the voltage and current readings. As the students take the data, they should try to watch the fluctuations in the current and the voltage, and use a method agreed on by the lab group to figure out what reading they will use.

After the data is acquired, the students need to calculate the power from their readings of voltage and current. The students should display their data in tabular form, being careful to use appropriate units throughout. The calculated values of the power are then plotted versus time, either by using a spreadsheet program such as Excel, or by hand. The lab groups then determine what the best-fit curve to their data looks like.

After the data have been graphed, the students then determine how much energy from the battery was dissipated in the course of the lab. The energy output is given by the integral of the power over time, which is the area under the curve that they have plotted. The easiest way to calculate this area is using a trapezoidal approximation, which is illustrated in Figure 8.2. For those not familiar with this numerical method, a short description is given here. We begin with values of the power P calculated at equal time intervals t . In the lab there are N such time intervals. There are $N + 1$ values of the power, starting from the initial value P_0 and ending with the final value P_N . The energy E_{i+1} dissipated in the interval t_i is given by the area under the curve between points P_i and P_{i+1} . This value is given by the trapezoidal rule as

$$E_{i+1} = [(P_i + P_{i+1})/2]t_i \quad (8-4)$$

In this experiment the time intervals t_i all have the same values.

Students may wonder about the accuracy of this procedure. Figure 8.2 might indicate to them that there is an inherent error involved, and they would be right. The error Δf involved in numerically integrating a function $f(x)$ over the interval $[a, b]$ is given by

$$\Delta f = (h^2/12)(b-a)(d^2 f(\zeta)/dx^2) \quad a < \zeta < b \quad (8-5)$$

(i.e. the second derivation of f is evaluated at ζ). Here h is the width of the sections into which

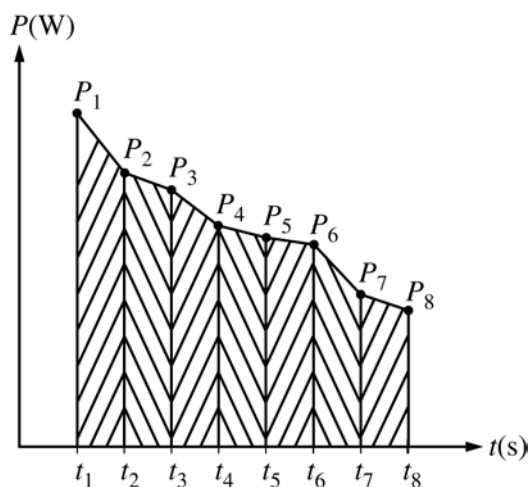


Figure 8.2

the interval $[a, b]$ is subdivided.¹ Students should note that the size of the error is directly proportional to the square of the width of the time interval. Reducing the time interval by a factor of two can reduce the error by a factor of four. There are more sophisticated methods available to calculate the area under the curve, such as Simpson's rule, but the trapezoidal method is accurate enough for this lab. The reason is that the data themselves have an error associated with them that swamps the error ΔE .

Experiment 2

In the second lab the students fit a curve to data generated in the same manner as in Experiment 1. The second experiment may be done with the data collected in Experiment 1, or with a new set of data collected in a second lab period. This lab points up the difference between two approaches to curve fitting that we often take in lab.

Usually when we fit a curve in lab, we rely on a good "eyeball" fit. We expect roughly the same number of points to be above and below our best-fit curve. We also attempt to minimize the distance between the points and the curve that we fit to the data. Sometimes, when we know or expect the data to fit a straight line, we calculate the least-squares fit for a linear relationship between the independent and dependent variables in the data. Such calculations are easily done with a spreadsheet program, or with a programmed calculator.

Problems arise when the data do not fall neatly on a linear plot, a log-log plot, or a semilog plot. When this is the case, students can still usually draw a curve freehand that seems to fit the data well. This is often adequate for purposes of interpolating data. But there is no analytic

¹ B. Carnahan, H. A. Luther, J. O. Wilkes, *Applied Numerical Methods*, (John Wiley and Sons, 1969, 70-72.

function that would allow them to extrapolate from their data. Of course, any extrapolation is beset by problems. Questions arise such as the applicability of the experimental conditions to values of the experimental variables outside the measured range. Nonetheless, extrapolation and prediction are often what scientists are called upon to do. This exercise provides a useful introduction to the problems extrapolation involves.

The students set up Experiment 2 just like Experiment 1, taking data at five-minute intervals for 45 to 50 minutes. This gives the students 10 or 11 data points. Unless something has gone wrong in the experiment, the data will show the output power of the battery decreasing in time in a nonlinear manner. The students need to answer the following two questions.

- (a) What is the analytical form of the best fit to this data?
- (b) Using their analytical fit, what is the predicted power output of the battery in 24 hours?

If students have access to a spreadsheet program that will provide log-log and semilog plots, they can obtain analytical fits in the form of Equation 8-6 for semilog plots.

$$P = A \exp(-t/\tau) \quad (8-6)$$

Alternatively for log-log plots they obtain Equation 8-7.

$$P = Bt^n \quad (8-7)$$

In Equations 8-6 and 8-7, A and B are constants, τ is the time constant for the exponential decay, and in this case, n is a negative number. Once the data has been plotted and fit, the students should use their fit to predict the battery output power 24 hours later. They leave the circuit connected, and the next day check the actual power output of the battery with their predicted value.

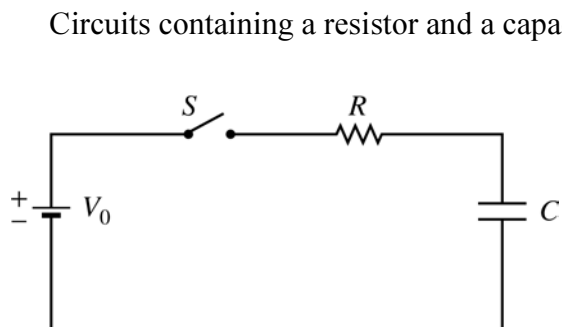
If a spreadsheet program with curve-fitting capabilities is not available, students can perform the lab using semilog paper for the exponential decay, and log-log paper for the power law decay. They do this by making the best linear fit to the data in these two cases. The slope of the line on the semilog paper gives the reciprocal of the time constant τ . The slope of the line on log-log paper gives the exponent n in Equation 8-7.

This still leaves the problem of how to determine the constants A and B , which requires some calculus. One method is to integrate the area under the curve analytically and fit it to the value given by the numerical integration. The first step in this process is to integrate the area under the power versus time curve from 5 minutes to 50 minutes using the trapezoidal rule outlined in Experiment 1. The second step is to perform the same integration analytically, using the values of τ and n from the semilog and log-log graphs respectively. The constant A may be found by setting the analytic result for the exponential function, which involves the factor A , equal to the numerical result. The constant B may be found by setting the analytic result for the power law integration, which involves a factor of B , equal to the numerical result.

Now that the students have determined the values of the constants for Equations 8-6 and 8-7, they may make their predictions. As noted above, one prediction may be made for the power output after 24 continuous hours of operation. The students might also make predictions for the power output at the 2-hour mark, and compare that to the predicted value, if time allows. All of the data analysis need not be done before the data are taken at either the 2- or 24-hour intervals. The agreement of the measured power output at the 24-hour mark will probably not agree very well with the predicted value, while the 2-hour agreement is usually better.

LAB NINE

RC Time Constant (Only in Physics C Syllabus)

Introduction**Figure 9.1**

Circuits containing a resistor and a capacitor connected in series are among the easiest circuits exhibiting time-dependent behavior for students to investigate. A simple circuit for investigating this time-dependent behavior is shown in Figure 9.1. When the switch S is closed, the circuit is complete and current begins to flow, charging the capacitor C . The voltage drops around the loop must equal the charging voltage V_0 . We write this as

$$V_0 = V_C + V_R \quad (9-1)$$

Here V_C is the voltage drop across the capacitor C , and V_R is the voltage drop across the resistor R . We set V_C equal to Q/C , where Q is the charge on the capacitor. We also set V_R equal to RI , using Ohm's Law. Substituting these two expressions into Equation 9-1 we obtain

$$V_0 = Q/C + RI \quad (9-2)$$

Now we exploit the fact that the current I is the time derivative of the charge flowing through the resistor R to obtain the first-order differential equation

$$V_0 = Q/C + R(dQ/dt) \quad (9-3)$$

Solving this differential equation for $Q(t)$ we obtain

$$Q(t) = V_0 C (1 - e^{-t/RC}) \quad (9-4)$$

Differentiating this expression with respect to time gives the current I as a function of time:

$$I(t) = (V_0/R)e^{-t/RC} \quad (9-5)$$

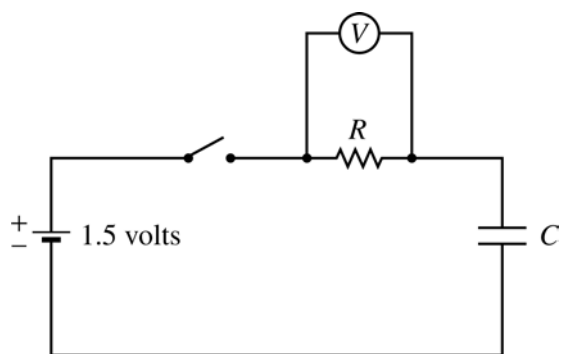
The voltage drop V_R across the resistor R is given by $RI(t)$, so we have

$$V_R(t) = V_0 e^{-t/RC} \quad (9-6)$$

We see that the voltage across the resistor is exponentially decreasing. In this lab we measure the voltage $V_R(t)$ to see if it corresponds to the voltage predicted by this equation.

Experimental Procedure #1

This experiment is carried out using the circuit shown in Figure 9.2. The **voltmeter** is a **digital multimeter (DMM)** with an internal resistance of several megohms. The **battery** is a **1.5 volt D cell**. The resistor is a $\frac{1}{4}$ W resistor with a resistance between 10 kilohms and

**Figure 9.2**

100 kilohms. The capacitor is a **large electrolytic capacitor** with a capacitance of 1000 μF to 10,000 μF . The students should be given the capacitor and asked to determine the resistance required to make the product of resistance and capacitance approximately 100. From Equation 9-5 it can be seen that RC has units of time, and is equal to the time required for the voltage to drop to $1/e$ of its original value. The product RC is referred to as the *time*

constant for the circuit. In this case, a value of 100 seconds for the time constant gives a reasonable charging and discharging time for the experiment.

The reason for giving the students the capacitor first and asking them to find the value of the resistor is that big capacitors are large and expensive items while resistors are cheap. It is more cost effective to start with a single size of capacitor, bought in quantity for this lab, than to buy an array of large capacitors that find little additional employment in the introductory physics course.

To carry out the experiment, students close the switch S in Figure 9.2, and read the voltmeter every 10 seconds until the voltage goes to zero. The data may then be plotted as voltage versus time to show the exponential decrease of the voltage drop across the resistor with time. The data are then plotted a second time on a semi-natural log plot of voltage versus time. The slope of this second graph is equal to $(-1/RC)$.

Students may then compute the time constant RC from the two graphs and compare the two values they obtain. To obtain the time constant from the first graph, students may draw a best fit curve to the data, then locate the point on the curve where the voltage is equal to $1/e$ of its initial value. The time when that occurs is the time constant RC . The time constant is found on the second graph by determining the slope, then setting that value equal to $(-1/RC)$.

After the two values of RC are determined, students may then determine the actual value of the capacitors used in the lab. The digital multimeters may be used as ohmmeters to measure the actual value of the resistors, and then the capacitance may be determined from the time

constant RC . Students may then compare the nominal value, that is the value printed on the capacitor, to the value they calculate. They should determine if the value they obtain lies within the stated tolerance of the nominal value. For example, suppose the students use a 10 kilohm resistor, and obtain a time constant of 116 seconds. This yields a capacitance of 11,600 μF . If the capacitor they are using has a nominal value of 10,000 $\mu\text{F} \pm 20\%$, this means the time constant may be expected to yield a value between 8000 μF and 12,000 μF . Thus the value of the capacitance calculated from the experimental data agrees with the nominal value of the capacitor, within the stated tolerance.

Experimental Procedure #2

This experiment requires an **oscilloscope**, a **function generator**, a **solderless breadboard**, a **resistor**, and a **capacitor**. This equipment is wired up as shown in Figure 9.3. The oscilloscope is used to measure the input waveform to the RC circuit and the waveform across the resistor. The function generator supplies the input waveform, in this case a square wave. The capacitor charges and discharges once during each complete cycle of the square wave. This charging and discharging causes a current to flow through the resistor. The voltage drop across the resistor due to the current flowing through it is displayed on the oscilloscope.

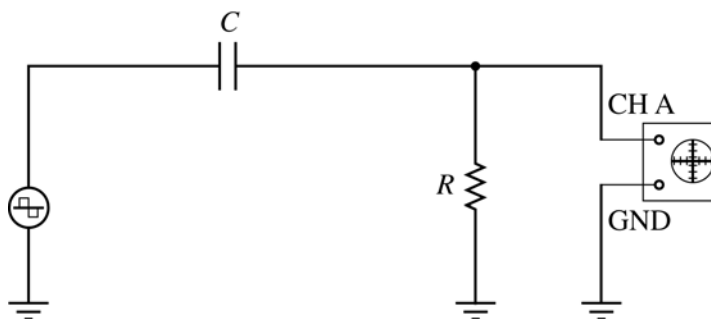


Figure 9.3

Now we consider some actual numbers, in order to anticipate what we will see on the oscilloscope. It is a good idea to have the students do this as well, so that they think through the behavior of the circuit. We begin by assuming that the function generator is set to 1 kilohertz. We further assume that the value of the resistor is 1.5 kilohms, and the value of the capacitor is 0.1 μF . The RC circuit has a time constant equal to the product of the values of the resistor and capacitor. For the values given above, the time constant is 0.15 milliseconds.

The function generator supplies a voltage $+V$ during the charging phase of the 1 kHz signal. If the square wave is symmetrical, that is, if the voltage is equal to $+V$ during one-half of the period of the wave and zero during the other half, the charging voltage is supplied for

0.5 milliseconds. This allows the capacitor to charge up to 97% of $+V$. When the input voltage drops to zero during the second half of the 1 kHz square wave, the capacitor discharges. The students can observe the charging and discharging cycle easily on the oscilloscope. The grid on the face of the oscilloscope is used to obtain the time that the capacitor takes to charge to $1/e$ of the input voltage. This time is equal to the time constant for the RC circuit, and can be compared with a value for the rise time calculated from the nominal values of the resistor and the capacitor.

The resistors used in this lab commonly have a tolerance of $\pm 5\%$. The tolerances of the capacitors are often great, ranging from 10% to 50%. It is a good idea to determine the tolerances of the components and to inform the students what those tolerances are, before they compare their experimental values to the value expected from the nominal values of the resistor and capacitor.

Equipment Tip

Since some classes may not have access to function generators, a simple circuit is provided in Figure 9.4 that supplies a square wave with a frequency of 1 kHz. The circuit uses an integrated circuit relaxation oscillator, two resistors, a capacitor, and a 9-volt battery.

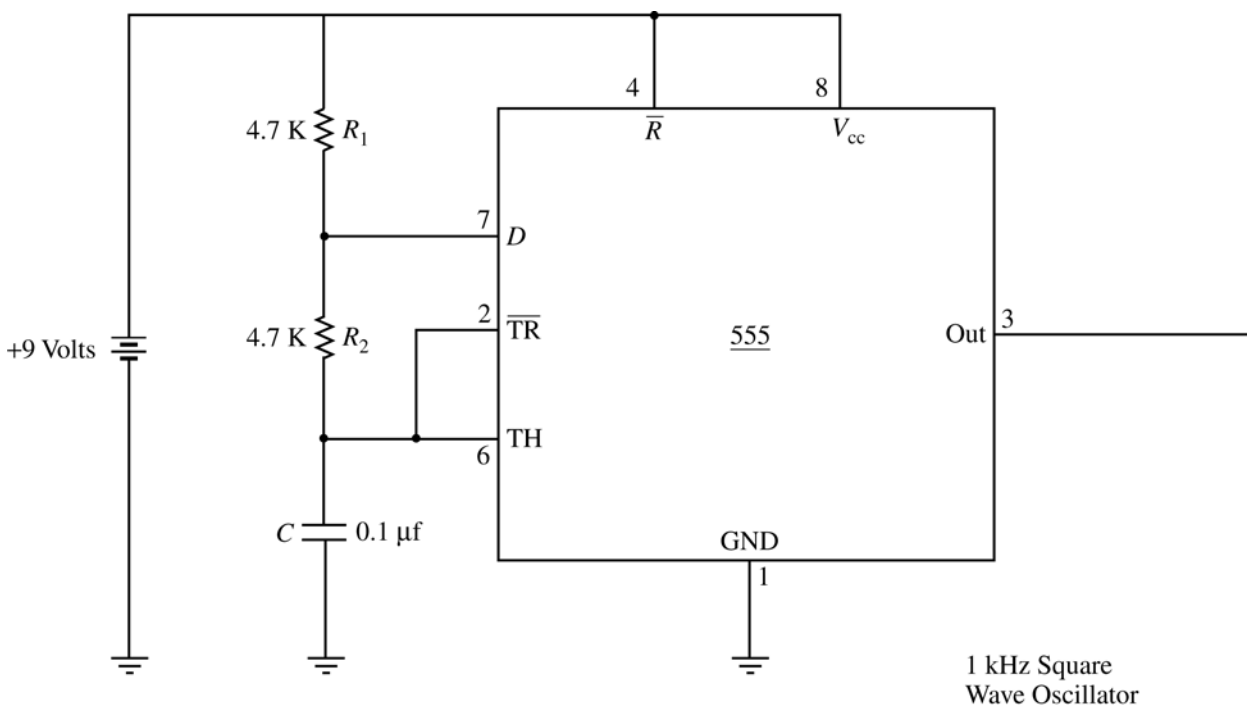
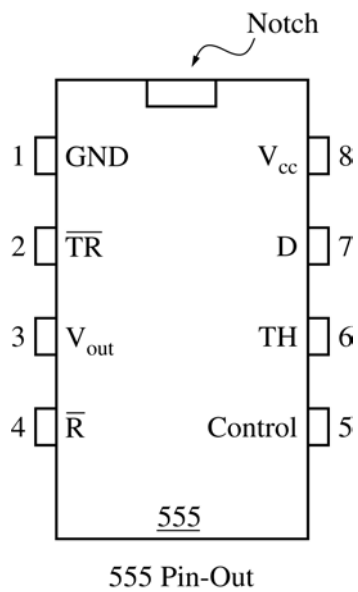


Figure 9.4

**Figure 9.5**

The oscillator chip, a 555, is inexpensive and readily available. The battery is the most expensive component in the circuit, as the total cost of the other components is less than a couple of dollars. A greatly enlarged top view of the oscillator chip, and an identification of its pins, is supplied in Figure 9.5. The period T of the oscillator is given by Equation 9-7.

$$T = 0.693(R_1 + 2R_2)C \quad (9-7)$$

The oscillator may be constructed on the same solderless breadboard that you use to construct the RC circuit.

LAB TEN

Magnetic Fields*

Introduction

Labs in which students made more than qualitative investigations of the properties of the magnetic field have been more difficult to put together until the recent advent of inexpensive Hall-effect probes. In this lab two lab exercises involving the measurement of magnetic fields

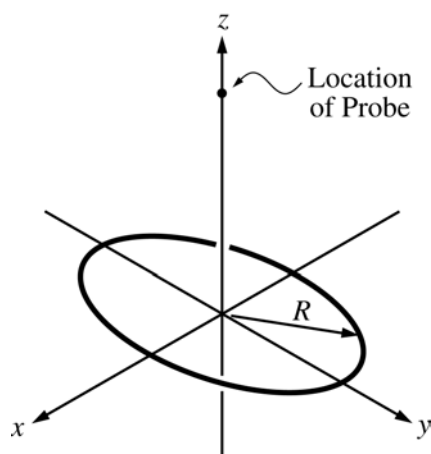


Figure 10.1

are described. The first involves the measurement of the magnetic field due to a current loop. The measurement can be undertaken either with a commercially available unit, or with an inexpensive gaussmeter whose construction is described here. The gaussmeter has a resolution of $\pm 0.1 \mu\text{T}$. This gaussmeter is used in the second lab exercise to study the direction and magnitude of the Earth's magnetic field.

Theory

The problem of determining the magnetic field due to a current loop is a standard one. We posit a loop of radius R carrying a current I and lying in the x - y plane, as in Figure 10.1, and determine the field along the z -axis. After applying the Biot-Savart law, we find that the field $B(z)$ is given by Equation 10-1.

$$B(z) = (\mu_0 I / 2) \left[R^2 / (R^2 + z^2)^{3/2} \right] \quad (10-1)$$

If we have a coil of N turns, Equation 10-1 becomes

$$B(z) = N(\mu_0 I / 2) \left[R^2 / (R^2 + z^2)^{3/2} \right] \quad (10-2)$$

The difficulty of carrying out a lab involving this situation may be seen by examining some typical numbers. Let us suppose that the radius is 0.1 meter, that the current is 1 amp, and that the coil consists of 100 turns. The field at the origin is only 6.2 gauss, or 0.62 mT. At a z value of 0.1 meters, it is 2.2 gauss, or 0.22 mT. These fields are difficult to detect without a specialized piece of apparatus.

One way of getting around this problem of small fields is to use an AC current in the coil, and to monitor the field using a small pickup coil. The idea is that the current in the big coil

* This lab requires the teacher or students to construct some electronic apparatus. Teachers with little or no experience with electronics may wish to forego this lab, or to undertake it as an extended project with students.

induces a current in the small coil, which may be monitored on an oscilloscope. The two difficulties are that the pair of coils has a coupling that is frequency dependent, and that the phase between the signals in the primary and secondary are also frequency dependent. There is also the question of whether it is wise, pedagogically, to treat an AC circuit as though it was a DC circuit.

Magnetic Fields 1

Procedure

The equipment needed for this lab is a **coil**, a **power supply**, a **meter stick**, a **ring stand**, an **ammeter**, and a **magnetic field probe**. The coils may be made beforehand, or the students may make them as part of the lab exercise. Large diameter ($R \geq 0.1$ meter) coils are good, as they reduce any errors that come from having the probe slightly off the z-axis. If the power supply may supply 1 to 2 amps, a coil of 100 to 200 turns gives a good strong B field that will be much larger than the Earth's field out to a distance of $2R$ to $3R$.

The coil may be wound on any circular form of the desired radius. Cake pans are good examples. After the students wind the desired number of turns, they should carefully remove the coil from the form, and then wrap the coil with tape to prevent it from immediately transforming itself into a gigantic tangle of wire.

The coil may be driven directly from the power supply if the power supply is current limited. Otherwise, a load resistor must be used to limit the current drawn by the coil. The load resistor must have a power rating adequate for the current being drawn by the coil. Calculating the size of the power resistor needed for this task should be one of steps that students complete to prepare for the lab.

If you don't have a power supply that can provide an adequate current, a 6-volt lantern battery may be used. Again, the calculation of the size of the needed load resistor is an essential part of the lab.

The coil is now laid flat on the table. The magnetic field probe is attached to the ring stand with a clamp, and lowered until the probe is in the center of the coil. It may be necessary to raise the coil above the ring stand base in order to get the probe into the center of the coil. This can be done by laying the coil on a large book. The coil is energized, and the field strength measured. The current is then changed, either by adjusting the power supply or by changing the resistance of the load resistor, and the field is measured again. This procedure is repeated until the students have 5 or 6 values of the magnetic field at different current values. This part of the lab demonstrates the linear dependence of the field on the current in the coil.

The current in the coil is then set to its maximum value. The probe is raised 0.02 meters, and the magnetic field measured again. This procedure is repeated until the probe is about $3R$ above the plane of the coil. This data is used to verify Equation 10-2.

The coil circuit is then opened, so that no current flows in the coil. The magnetic field is again measured at every point from $z = 0$ out to $z = 3R$ where data was taken initially. These background readings are subtracted from the data taken on the first run in order to obtain the field due to the coil alone. It is best to measure the background field at all points, because there may be significant magnetic anomalies in the lab arising from ferrous ring stands, magnetized tools, or permanent magnets that are in the drawers of the desk below the surface of the lab table or bench.

Analysis

The first part of the analysis is graphing the current versus field data. This data should yield a straight line with a slope of $N\mu_0/2R$. The students should be asked if it makes a difference in their determination of the slope whether the background value is subtracted or not.

The second part of the graphical analysis is more demanding. The students need to first subtract out the background values from field readings. They then plot the values of the coil's magnetic field versus the distance z . They may rewrite Equation 10-2 as

$$B(z) = D(R^2 + z^2)^{-3/2} \quad (10-3)$$

Here the constant D is given by

$$D = N\mu_0 I R^2 / 2 \quad (10-4)$$

The value of the field measured at $z = 0$ is used to fix D . Using Equation 10-3, a curve is then drawn of the theoretical values of the magnetic field. The experimental data are plotted to see if they fall on this theoretical curve. The agreement between theory and experiment is very good.

Yet another graphical exercise is to plot the magnetic field versus $(R^2 + z^2)^{-3/2}$. This plot generates a linear fit whose slope is given by D in Equation 10-4. Since the number of turns N , the current I , and the radius of the coil R are all known, the graphical D value may be compared with the D value computed from these known values.

In making this comparison, the students should consider sources of error in D . The number of turns is known to ± 1 turn, and the current is known to within $\pm 2\%$ with most ammeters. The radius R is the most uncertain of the values, and the students should think carefully about how to determine R and its uncertainty. The most straightforward method is to average the inner and outer diameter of the coil across four or five diameters. The error that results from these

measurements should be taken into account when the two values are compared. The total error from N , I , and R is often about 5%, and the two D values usually agree to within that accuracy.

Apparatus

The apparatus is designed to allow students to measure magnetic fields with a sensitivity of $\pm 0.1 \mu\text{T}$. It requires a minimum of electronic construction skills, and takes about 2 hours to build. The circuit may be built on a solderless breadboard as part of the student lab, or constructed and housed in a small cabinet or box as a permanent piece of apparatus.

The gaussmeter is built around an inexpensive Hall-effect device, the 3515 Linear Hall-Effect Sensor[♦]. The sensor requires a +5 volt supply, and provides a signal that is centered at around 2.5 volts. The output of the 3515 is 50 mV/mT with an accuracy of $\pm 10\%$.

The sensor is mounted on a small piece of circuit perfboard. A piece $\frac{3}{8}$ inch wide and 1.5 inches long works well. The leads for the signal, +5 volt supply, and ground should be 24 AWG copper wire or smaller. Thicker wires make it difficult to maneuver the probe easily. The probe may be glued or epoxied to the perfboard for a more stable mounting. The probe is designed so that a magnetic field coming into the device from below results in an increase in the signal voltage, while a magnetic field coming into the device from above results in a decrease in the signal voltage. Here “above” refers to the side of the 3515 with lettering on it.

If you want a probe to use in determining the magnetic field in a long solenoid, the easiest way to do it is to mount the 3515 on the end of a wooden dowel so that the lettering on the 3515 faces outward from the end of the dowel. The dowel may then be inserted into the solenoid, and the magnetic field measured as described above.

[♦] See “Measurement and Analysis of the Field of Disk Magnets,” Martin Connors, *The Physics Teacher*, May 2002, pp. 308-311.

The circuit is shown in Figure 10.2. The output from the 3515 goes to an op amp U_1 that is configured as an inverting amplifier with a gain of 10. The output from U_1 goes to U_2 , a

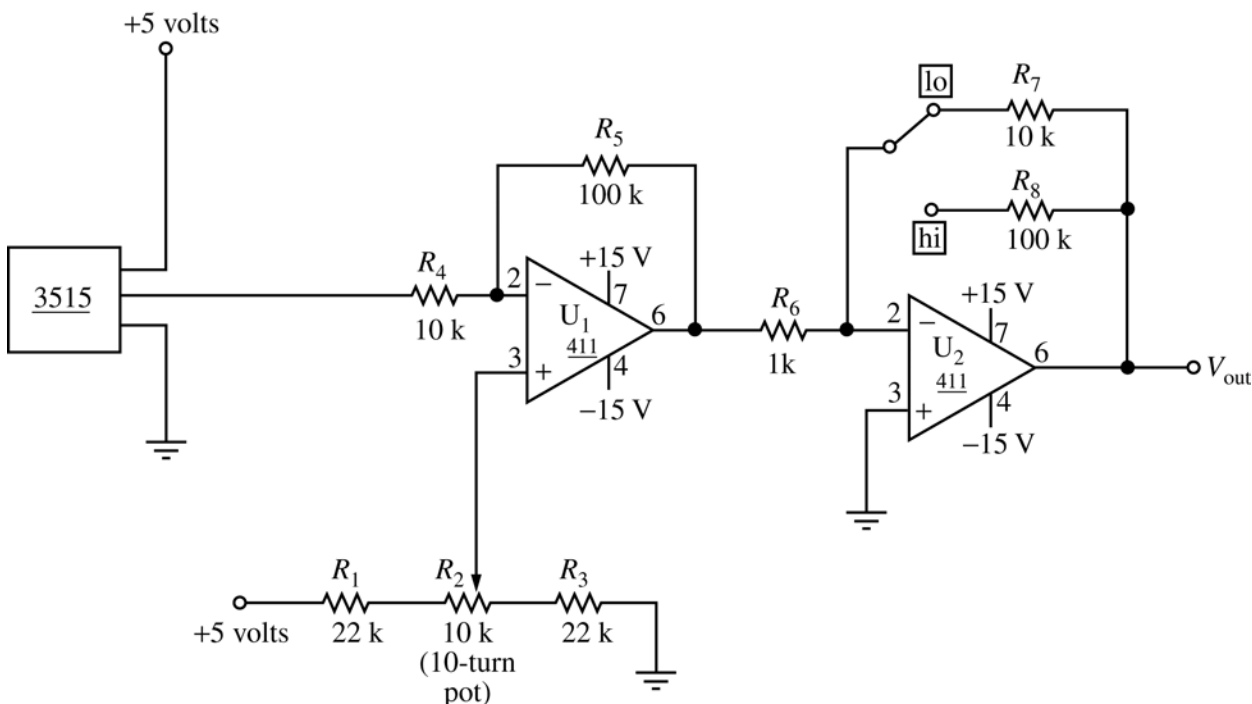


Figure 10.2

second op amp configured as an inverting amplifier with a gain of either 10 (low setting) or 100 (high setting), depending on which resistor is in the feedback loop. This increases the sensitivity of the probe by a factor of 1000 when used at the high setting, or $50 \text{ mV}/\mu\text{T}$.

The variable voltage divider consisting of R_1 , R_2 , and R_3 requires some explanation. The output from the 3515 consists of excursions around a voltage of 2.5 volts. If this output from the probe were simply amplified, it would quickly pin the op amp output to the supply voltages of positive or negative 15 volts. The variable voltage divider allows the first op amp U_1 to subtract off that 2.5 volt baseline voltage, and amplify only the departures from that baseline.

The probe output is temperature dependent, as it is based on a solid-state Hall-effect sensor. The op amps U_1 and U_2 may be any general-purpose op amp, but 411s are better than 741s. The op amps should be mounted in sockets, as soldering directly to the op amp leads may easily damage the op amps.

The output of the circuit goes to a digital multimeter used as a voltmeter. As the multimeter has a sensitivity of at least $\pm 5.0 \text{ mV}$, the probe has a sensitivity of $\pm 0.1 \mu\text{T}$.

The power supply voltages are ± 15 volts, and +5 volts. Some lab power supplies or electronics trainers have these outputs readily available. If not, the supply shown in Figure 10.3

is easy to construct. It consists of three regulator chips, a 7815, a 7915, and a 7805, that provide +15 volts, -15 volts, and +5 volts respectively, from a set of four 9-volt batteries. It is best to remove the batteries from the unit when it is not in use. The advantage to using batteries is that the unit is now portable.

The operation of the probe unit is simple. It is best to start with the gain selector set to low. The unit is turned on, and the zero-adjust potentiometer R_2 is adjusted to null the reading on the multimeter. The gain may then be switched to high, and the zero-adjust pot tweaked to null the output.

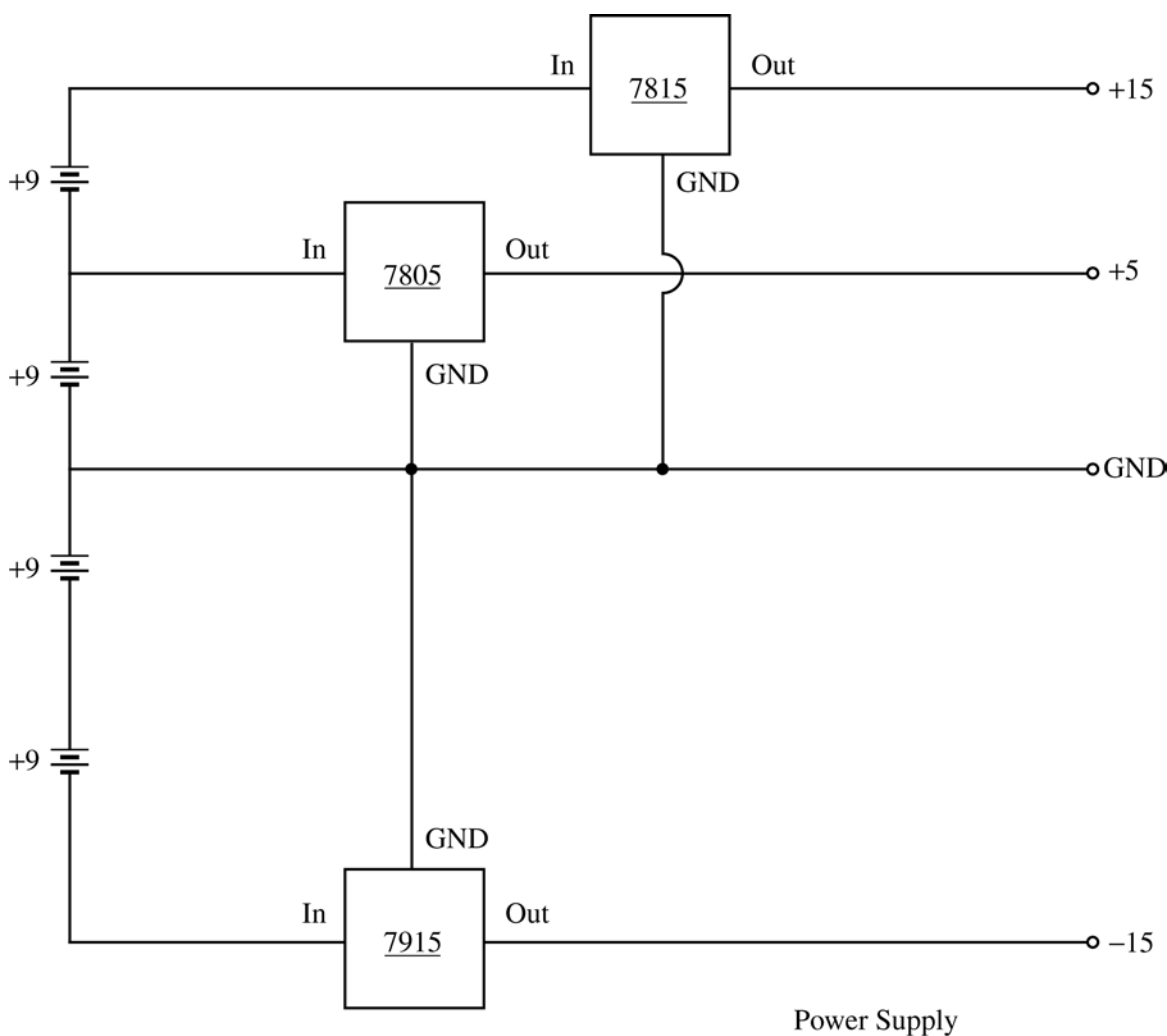


Figure 10.3

Magnetic Fields 2

Procedure

This method for obtaining the magnitude of the Earth's magnetic field and the dip angle is straightforward.

For this lab exercise the students need a **gaussmeter** with a sensitivity of $0.1 \mu\text{T}$, such as the one described in Magnetic Fields 1. The probe should be one that is easy to level. A **spirit level** is adequate to determine the orientation of the probe. A **non-magnetic ring stand and clamp** are also needed.

The gaussmeter probe described above should be mounted on a wooden dowel that is about 6 inches long. The dowel is then mounted in a ring stand clamp and set about 24 inches above the lab bench or table. The ring stand is taped to a rectangular piece of cardboard. A ruler is taped to the lab bench, and the cardboard on which the ring stand rests is positioned snugly next to it, as shown in Figure 10.4.

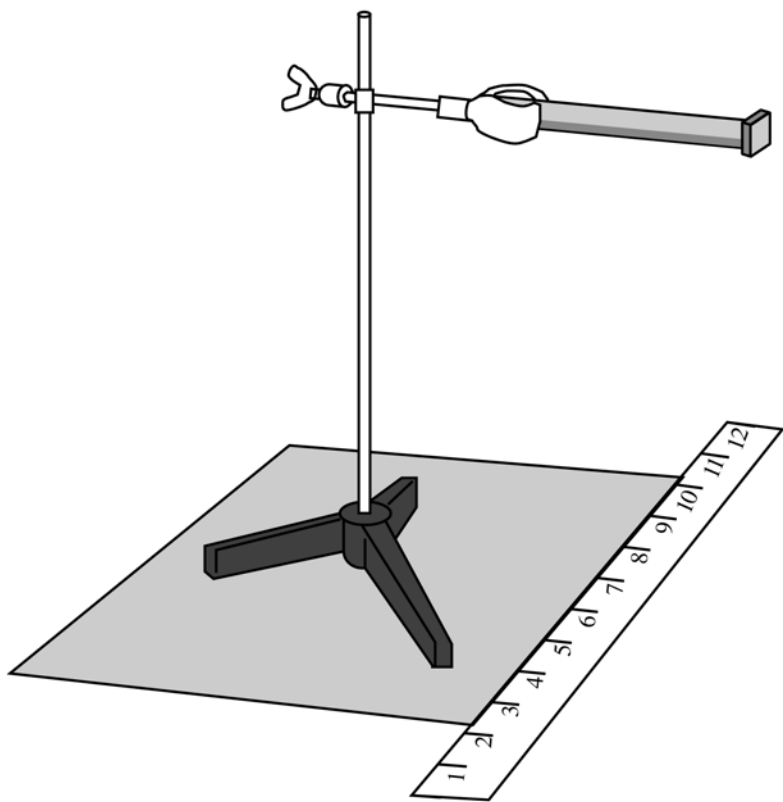


Figure 10.4

to it, as shown in Figure 10.4.

The dowel is made level using the spirit level for alignment. A voltage reading V_{1x} is taken. The dowel is then rotated so that the sensor is facing 180° opposite to the original orientation. A second voltage reading V_{2x} is taken.

The cardboard on which the ring stand rests is now rotated by 90° . The procedure used for the x -direction is repeated, so that the students obtain two voltages V_{1y} and V_{2y} . For the z -direction the probe is oriented so that the dowel is vertical, so that the Hall-effect device glued to its

end is horizontal. The spirit level is again used to align the probe, and two readings V_{1z} and V_{2z} are taken.

The analysis of the data is simple. If the sensitivity of the gaussmeter is $50\text{mV}/\mu\text{T}$, then the fields in the three directions are given by

$$B_x = (V_{1x} - V_{2x}) / (50 \text{ mV}/\mu\text{T}) \quad (10-5a)$$

$$B_y = (V_{1y} - V_{2y}) / (50 \text{ mV}/\mu\text{T}) \quad (10-5b)$$

$$B_z = (V_{1z} - V_{2z}) / (50 \text{ mV}/\mu\text{T}) \quad (10-5c)$$

The magnitude of the Earth's magnetic field B_{Earth} is then given by

$$B_{\text{Earth}} = (B_x^2 + B_y^2 + B_z^2)^{1/2}$$

The dip angle ϕ of the field is given by

$$\phi = \tan^{-1} \left[B_z / (B_x^2 + B_y^2)^{1/2} \right]$$

LAB ELEVEN

Geometrical Optics: Determining the Index of Refraction

Introduction

There are many ways to illustrate Snell's law in the classroom, and a large number of laboratory exercises can be used to determine the index of refraction. Here we present one method in which the students explore the use of simple geometry and Snell's Law in order to determine the index of refraction of a rectangular slab.

Snell's Law seems simple as it is presented in most textbooks. Consider a beam of light traveling in a medium that has an index of refraction n_1 striking a boundary at an angle of incidence α , as in Figure 11.1. If the second material has an index of refraction n_2 , the beam of light leaves the boundary at an angle of refraction β , where β is given by Equation 11-1.

$$n_1 \sin \alpha = n_2 \sin \beta \quad (11-1)$$

It is useful to mention to students that this equation may be derived by applying the condition

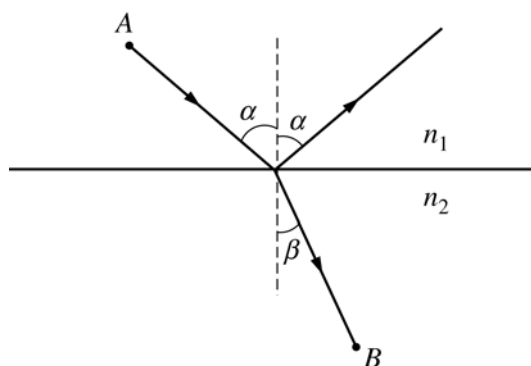


Figure 11.1

that light travels in the shortest time from point A in medium 1 to point B in medium 2. While the application of calculus necessary to carry out the proof of this is beyond the requirements of the Physics B course, students should be apprised of this useful application of a minimum principle in physics. This helps raise physics beyond the application of an array of equations to the application of general principles that have validity and usefulness elsewhere in physics.

Theory

In this experiment the index of refraction of a rectangular slab is determined by measuring the distance the beam is displaced after it travels through the block, as shown in Figure 11.2. Here the slab has a thickness D , and the beam undergoes a transverse displacement S as it passes through the block. The problem for the students is to determine the index of refraction n_2 from measurements of D , S , and the angle of incidence α .

We first define a new distance R , which is the length of the path that the beam follows in the transparent slab. From Figure 11.2, we see that R is related to S by Equation 11-2.

$$S = R \sin(\alpha - \beta) \quad (11-2)$$

This may be rewritten, using a trig identity, as

$$S = R(\sin \alpha \cos \beta - \cos \alpha \sin \beta) \quad (11-3)$$

From Figure 11.2 we see that R is related to D through Equation 11-4.

$$D = R \cos \beta \quad (11-4)$$

Substituting Equation 11-4 into Equation 11-3 to eliminate R yields Equation 11-5.

$$S = (D/\cos \beta)[\sin \alpha \cos \beta - \cos \alpha \sin \beta] \quad (11-5)$$

This simplifies to the following:

$$S = D(\sin \alpha - \cos \alpha \tan \beta) \quad (11-6)$$

This may be rearranged to Equation 11-7, which allows us to find β .

$$\tan \beta = \tan \alpha - (S/D \cos \alpha) \quad (11-7)$$

Once we have found the angle of refraction β , we may then find the index of refraction n_2 from Equation 11-8.

$$n_2 = n_1 \sin \alpha / \sin \beta \quad (11-8)$$

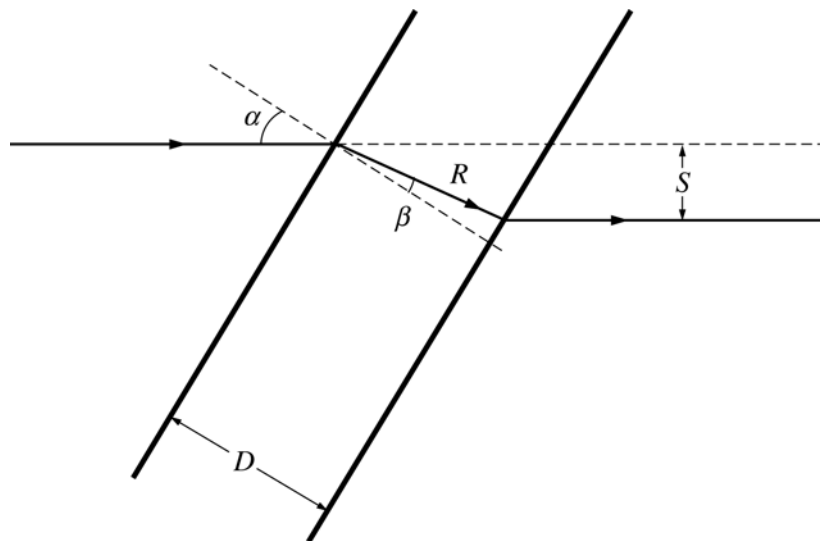


Figure 11.2

Apparatus

The experiment is carried out by sending a beam of light through a transparent block and measuring the transverse displacement S . The beam of light is best provided by a laser. The laser may be a laser pointer, although laser pointers often have a wide beam divergence on the order of several milliradians. A small **solid state laser** works better. Before turning on any of

the lasers, the students must be instructed in the basics of laser safety. Many laser pointers have outputs of several mW, making them Class IIIa or IIIb devices. If the beam goes from the laser directly into the eye, severe and permanent eye damage may result. Students must understand that lasers are not toys, and that misuse may easily cause irreparable harm to others, or themselves. The laser should never be turned on unless it is firmly mounted on the lab bench, and directed at the transparent block. The laser pointer and block should be arranged along the long axis of the lab table, in such a way that makes it as difficult as possible for a student to place his or her face in the beam path. Obstacles, such as screens, should be placed in the path of the reflected and refracted rays, so the beams do not stray beyond the measurement area.

The students need a rectangular slab of transparent material. A **slab of glass 3 or 4 inches thick** works well, but may be difficult to find. A **shallow tank made of glass or acrylic that is filled with water** also works well. The tank, 3 or 4 inches on a side and an inch high, may be easily fabricated out of acrylic or glass pieces held together with waterproof cement.

The student needs some way of measuring the angle of incidence α . A simple **protractor** works well. The tank and protractor may be set on a piece of paper that rests on a **slab of Styrofoam**. The slab provides a backing into which **straight pins** are pushed to mark the location of the laser beam. The entire setup is illustrated in Figure 11.3.

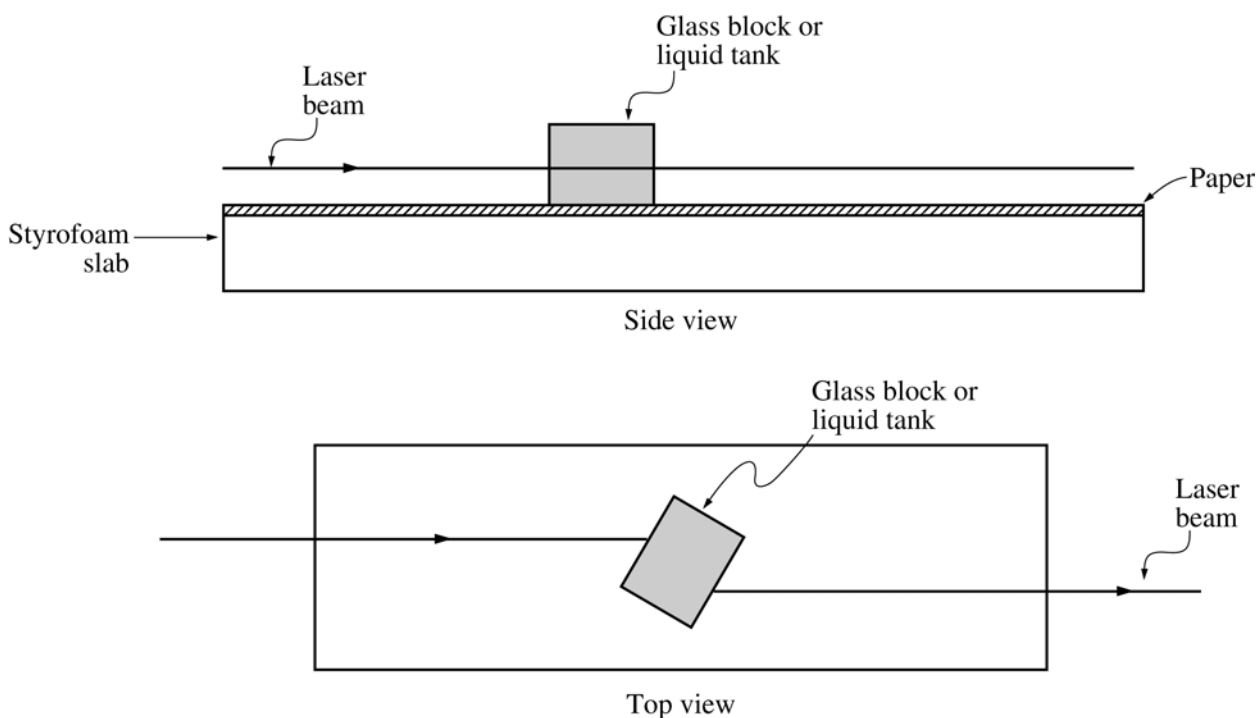


Figure 11.3

Experiment

The procedure consists of sending the beam through the slab at a number of angles, and marking the displacement of the beam. It is a good idea to tape the Styrofoam to the lab bench and pin the paper to the Styrofoam before taking any measurements. Once the laser is set up, the position of the beam should be marked on the paper by placing two pins in the paper. The pins should be placed so that the beam hits them before it gets to the slab. The pins should also be far enough apart so that it is easy to draw a straight line through them, and continue that line past the slab. A 4-inch separation is usually adequate.

The transparent slab and protractor are then placed on the paper in such a way that the beam goes through undeflected. This is used to mark the zero-degree angle of incidence. Two pins are used to locate the position of the beam after it leaves the slab.

The slab is then rotated to an angle of 30 degrees, and the new position of the beam after it passes through the slab is determined. Two pins are used to locate this new position of the beam. This process is continued by marking new beam positions after the slab is rotated to 40, 50, 60, and 70 degrees.

The angle of incidence is most easily determined by measuring the angle of deflection of the beam after it reflects from the slab's surface. The angle of incidence is one half of the angle of deflection, as shown in Figure 11.1. The reflected beam's location is also easily found using the same pin arrangement as for the transmitted beam. A typical set of data for a single reading is shown in Figure 11.4.

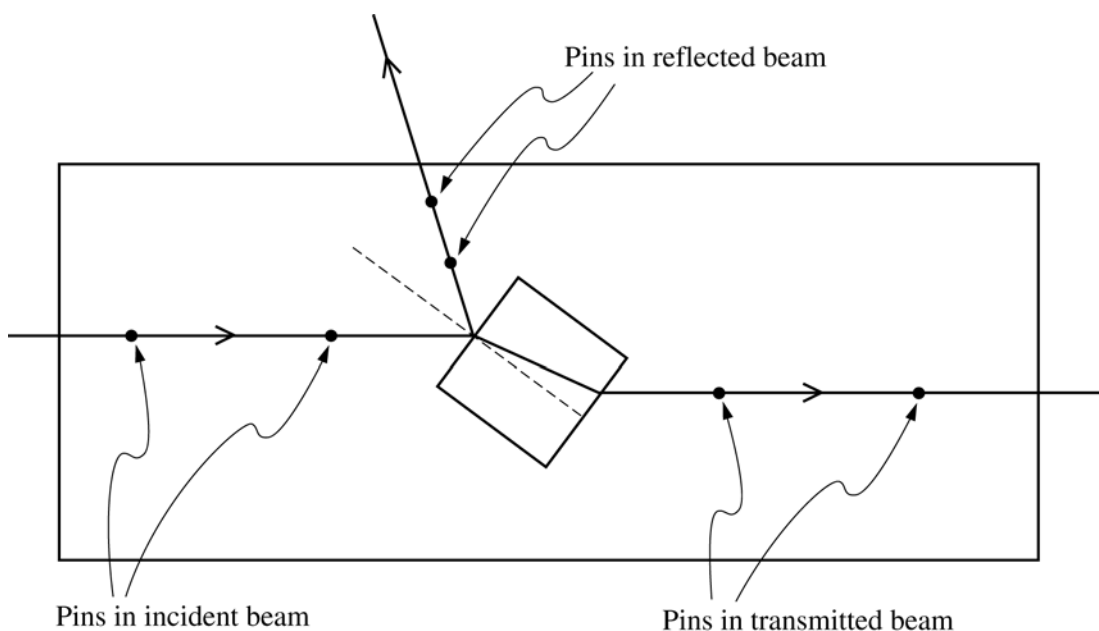


Figure 11.4

The sheet of paper with the pinholes in it is removed from the Styrofoam mounting board. The student then draws a line corresponding to the undeflected beam, and the five sets of straight lines corresponding to the transmitted and reflected beams. The student measures the angles of deflection in order to obtain the angle of incidence. The transverse displacement of the transmitted beam is measured to provide a set of five S values. The thickness of the transparent slab is measured and the student may proceed to the analysis.

Analysis

The data analysis can be carried out on a spreadsheet, but the presence of the trigonometric functions makes it just as easy to do by hand. Equations 11-7 and 11-8 are used to obtain values of n_2 from the data. The resulting n_2 values may then be compared with known values of the index of refraction for glass or water. Students should do some statistical analysis on their n_2 values, calculating an average value and a standard deviation. For students unfamiliar with the calculation of the standard deviation σ , it is given by Equation 11-9.

$$\sigma_x = \sqrt{\sum_i (x_{avg} - x_i)^2 / (N - 1)} \quad (11-9)$$

Here N is the number of data points, x_{avg} is the average value of the variable x , and the x_i are the individual data values for the variable x .

After the class does the experiment, they should compare n_2 values and the experimental uncertainty in n_2 . The values the students obtain should all agree to within $\pm 2\sigma_{n_2}$.

As an example, suppose a student obtains the following values for n_2 for water: 1.30, 1.35, 1.29, 1.30, and 1.36. The average value for these readings is 1.32. The standard deviation is 0.032, so that $n_2 \pm 2\sigma_{n_2}$ is 1.32 ± 0.06 . This agrees with the standard value of 1.33, to within the experimental uncertainty.

Comments on Geometrical Optics

There are many kits that are available from scientific supply houses that allow the students to explore the properties of lenses and mirrors. If your class spends more than a week or two on geometrical optics, these kits are a worthwhile investment. If you spend only a couple of weeks on geometrical optics, this lab may provide your class with enough material in data analysis and experimental procedure.

LAB TWELVE

The Diffraction Grating

Introduction

Physical optics provides students with an opportunity to study the wave nature of light. The labs and demonstrations that the students encounter in physical optics allow them to better understand the concepts of modern physics that they encounter at the end of the Physics B course. One of the easiest experiments to perform in physical optics involves sending a monochromatic beam of light through a diffraction grating in order to determine the wavelength of the light source. Inexpensive diffraction gratings are available for less than a dollar apiece, and lasers, particularly in the form of laser pointers, are inexpensive as well. Red laser pointers cost less than \$20. A green laser pointer, while more expensive at \$200 or more, is useful to show the students how the dispersion of the grating depends on wavelength.

Theory

The theory of the diffraction grating is covered in most college physics textbooks. The example given usually begins with a two-slit aperture as shown in Figure 12.1. A beam of light is incident on the aperture, and each slit acts as a point source of light. The two sources give rise

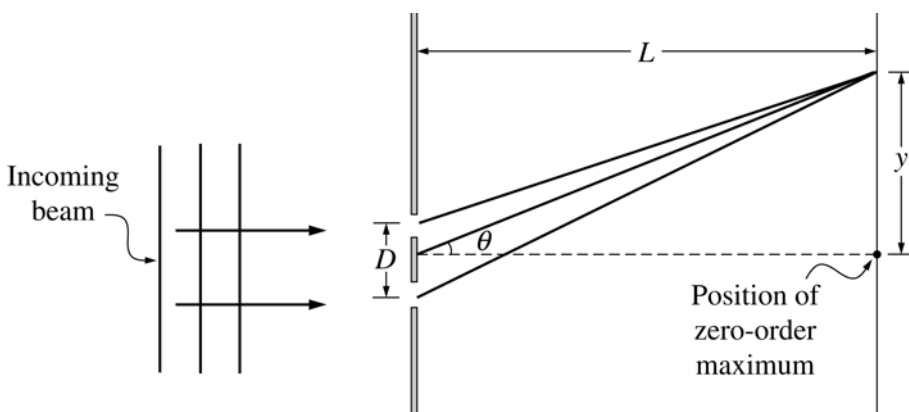


Figure 12.1

to an interference pattern on a screen that is a distance L from the apertures. We assume that L is much larger than the slit separation D . If the phase difference ϕ between the two waves is an even multiple of π , constructive interference results. Another way of

stating this condition is that the optical path difference between the two sources is an integer number of wavelengths. From Figure 12.1 we may write this as

$$D \sin \theta = m\lambda \quad (12-1)$$

where m is an integer (0,1,2,3,4, . . .) and λ is the wavelength of the light. We may rearrange this equation to

$$\sin \theta = m\lambda/D \quad (12-2)$$

If we wish to locate the maximum of order m on the screen in terms of distance y from the zero-order maximum, as shown in Figure 12.1, we may use

$$y = L \tan \theta \quad (12-3)$$

and then use Equations 12-2 and 12-3 to locate y . Students should note that as the wavelength λ increases, the angle θ increases as well. The dispersion of a grating is thus opposite to that of a prism, in which long wavelengths undergo less deflection than short ones. It is useful to demonstrate this behavior to the class using a clear incandescent light bulb, a prism and a grating so that they may understand this fundamental difference between the two dispersive optical components.

Experiment

Lab apparatus consists of a **diffraction grating** mounted in a holder such as a ring stand clamp, a sheet of paper used as a screen, and two or more sources of monochromatic light. The sources may be a **HeNe laser**, a **red laser pointer**, and a **green laser pointer or laser**. The HeNe laser has an output at 633 nm, while the red laser pointer has an output around 650-670 nm, depending on the laser diode used in the pointer. The green laser pointer has an output around 530 nm. The students use the HeNe laser to calibrate their gratings, and then use the gratings to determine the wavelength of the output of the laser pointers.

Before turning on any of the lasers, the students must be instructed in the basics of laser safety. Many laser pointers have outputs of several mW, making them Class IIIa or IIIb devices. If the beam goes from the laser directly into the eye, severe and permanent eye damage may result. Students must understand that these things are not toys, and that misuse may easily cause irreparable harm to others, or themselves. The laser should never be turned on unless it is firmly mounted on the lab bench, and directed at the grating. The laser pointer and grating should be arranged along the long axis of the lab table, in such a way that makes it as difficult as possible for a student to place his or her face in the beam path.

Once the grating, laser, and screen are set up, the students may turn the laser on and observe the interference pattern that results. Again, care should be taken to eliminate stray laser beams bouncing around the room. The beam is weaker after it passes through the grating, but can still cause eye injury. Students should be cautioned to not look at the apparatus until they are sure that a scattered or reflected portion of the beam will not hit them in the eye. One way of doing this is to look away from the apparatus as it is turned on, then slowly moving their head back and forth and looking to see if a bright spot appears on the wall in front of them when they move their head. If a bright spot appears, that means that the laser beam is passing through the space where their head was. The apparatus should be turned off, and realigned to eliminate the stray

beam. It is useful to mount the gratings so that the interference pattern appears along a vertical, rather than a horizontal axis, as this lessens the danger of stray laser beams in the lab.

The grating calibration should be done at one lab station in the classroom. Students bring their gratings to the lab station and mount the grating in the holder. They should tape or otherwise mount a piece of paper on a screen about 1 meter away from the grating. They mark the position of the zero-order maximum and the first-order maximum on the paper after the laser is turned on. The students need to determine how they mark the position of two maximums. They may choose to attempt to determine the center of the maximums, or to draw a circle around the maximum. They should describe whatever procedure they use in their lab report, and explain why they choose that procedure.

Once the maximums are located, the students then go to their own lab station and set up their laser pointer in the same way the HeNe laser and grating were set up. The students shine the laser beam through the grating, and mark the location of the zero-order and first-order maximums on a sheet of paper. They use Equations 12-2 and 12-3 to calculate D from the known wavelength of the HeNe laser, and then may calculate the wavelength of the output of the laser pointer.

Analysis

The students should carry out an error analysis in this lab to determine the accuracy with which they know the wavelength of the laser pointer. The sources of error are the measurements that the students use to determine the slit separation in the grating, and the measurements of the maximum of the interference pattern from the laser pointer. Here we present an example of the error analysis that may be done to complete this lab.

We begin with the determination of the slit separation in the grating. Suppose the screen is measured to be 0.950 meters from the grating, with an error of ± 0.002 meters. The distance between the zero-order maximum and the first-order maximum is measured to be 0.355 meters. The spots were 0.002 meters wide, so we assume that the error associated with this measurement is 0.004 meters. We then apply Equation 12-3 to calculate the angle θ . The minimum value of the angle occurs if y is 0.351 meters and L is 0.952 meters. Equation 12-3 then yields an angle of 20.2° . The maximum value of the angle occurs when y is 0.359 meters and L is 0.948 meters. The angle is then 20.7° .

Using Equation 12-2, we take λ as 633 nm. Inserting the minimum θ value in Equation 12-2, we obtain a D value of 1.83×10^{-6} m. Inserting the maximum θ value in Equation 12-2, we obtain a D value of 1.79×10^{-6} m. We take the average D value to be 1.81×10^{-6} m, with an uncertainty of $\pm 0.02 \times 10^{-6}$ m.

We then take the measurements for the laser pointer interference pattern. Suppose we found that the distance between the zero-order maximum and the first-order maximum was 0.370 meters, with the same uncertainty of ± 0.004 meters. The screen was 0.970 meters, with an uncertainty of ± 0.002 meters. Using Equation 12-3 as before, these data yield minimum and maximum angles of 20.6° and 21.1° , respectively.

Now we return to Equation 12-2. Using the minimum value of D (1.79×10^{-6} meters) and the minimum value of θ (20.6°), we obtain a wavelength of 629 nm. Using the maximum value of D (1.83×10^{-6} meters) and the maximum value of θ (21.1°), we obtain a wavelength of 659 nm, so the wavelength may be reported as 644 ± 15 nm.

In fact, this procedure overestimates the error in the experiment. But this procedure, as crude as it is, gives the students a more immediate feel for the error involved than if we hand them a set of formulas, particularly formulas involving the derivatives of trigonometric functions, that are necessary for a more accurate estimate of the error.

LAB THIRTEEN

Planck's Constant on the Cheap

Introduction

In 1899, when Planck put forward the hypothesis of a quantum of action, he did not envision it as a fundamental quantity. Rather, it was a parameter that conveniently led to the correct description of the blackbody spectrum. Today we see it much differently, and consider it to be one of the fundamental constants of nature.

Niels Bohr later used Planck's constant in his explanation of the energy levels of the hydrogen atom. One of the postulates Bohr used in his seminal 1913 paper was that the energy of the light quantum given off by an atom when the electron makes a transition from an initial state E_1 to a final state E_2 is given by

$$hf = E_1 - E_2 \quad (13-1)$$

where f is the frequency of the light emitted. Equation 13-1 is the cornerstone of atomic and molecular spectroscopy. By measuring the frequency of light emitted by an atom or molecule, we can build up a model of the energy states that are accessible to its electrons.

In this lab we work in reverse from the usual spectroscopic procedure. Here we have an electron of charge e undergo a transition as it moves through a potential drop V . In a light-emitting diode (LED) the electron emits a photon as it moves through this potential drop. Following Bohr's reasoning, we write that the frequency f of the light emitted during this transition is related to the potential drop V by

$$hf = eV \quad (13-2)$$

where e is the charge on the electron. We can easily rearrange this to

$$\begin{aligned} h/e &= V/f \\ hc/e &= V\lambda \end{aligned} \quad (13-3)$$

where c is the speed of light, and λ is the wavelength of the light emitted by the LED. By measuring the voltage drop through which the electron falls, along with the wavelength of the emitted light, we obtain a quantity equal to the three fundamental constants on the left side of Equation 13-3.

Apparatus

The apparatus required for this lab is straightforward to assemble, and the data easy to acquire. The circuit shown in Figure 13.1 is used to carry out the experiment. The power supply can be any combination of batteries from 3 to 9 volts, such as a couple of D cells, a nine-volt battery, and so on. R_1 is a 1-k Ω , $\frac{1}{4}$ -watt resistor that limits the current through the diode. The

diode with two arrows emanating from it is the LED. The voltage drop across the diode is measured with M_1 , an inexpensive digital multimeter (DMM).

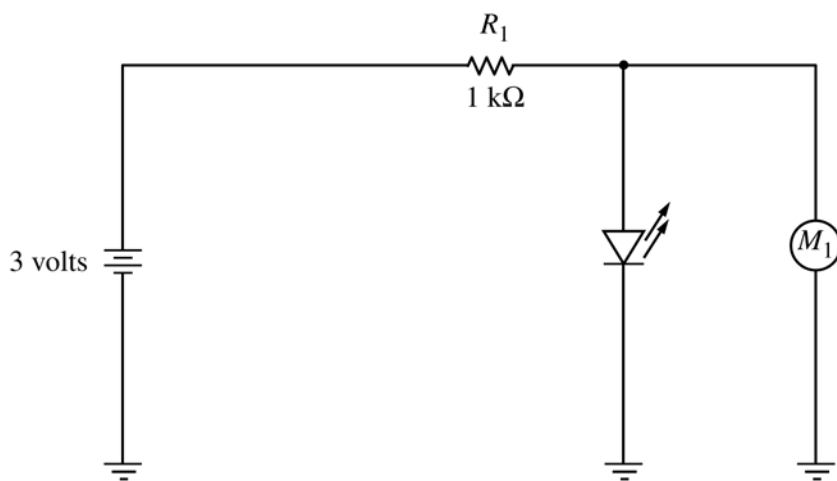


Figure 13.1

One way to do this lab is by using the circuit shown in Figure 13.1 and an assortment of LEDs. The LEDs should have outputs ranging from blue down to infrared. Cheap LEDs are available with output wavelengths in the infrared, red, yellow, green, and blue regions of the spectrum. A selection of five LEDs will yield five

different voltage drops V that may be plotted against wavelength. If we rearrange Equation 13-2 we may obtain

$$\frac{h}{e}f = V \quad (13-4)$$

so that a plot of V versus f should yield a straight line with a slope of h/e .

The obvious next question is where do the students get the wavelengths for the diodes. The short answer is that the wavelengths are often printed on the LED packaging for diodes available through retailers such as Radio Shack. A longer perhaps more satisfying answer is that students can guess the wavelengths for the LEDs with outputs in the visible by using the depictions of the visible spectrum often found in textbooks or science classroom wall charts. Before you eschew this approach, recall that the LED output is usually stated to within $\pm 10\text{ nm}$. Also, the LED output is not monochromatic. The wavelength listed on the LED package is the wavelength at which the intensity of the light output is highest. A plot of light intensity versus wavelength is peaked at that wavelength, but it has a full-width at half-maximum of around 20 nm as well. (Full-width at half-maximum refers to the width, in nanometers, of the intensity distribution at one-half of the maximum value of the intensity.) Experience shows that the students' guesses are actually accurate to within $\pm 20\text{ nm}$, and having the students guess the wavelengths does not affect the accuracy of the results. It is more useful to have the students guess, rather than to have them read a number from the package. Of course, if you use an infrared LED, that wavelength can be obtained from the package.

If the lab is particularly well equipped and has a spectrometer available, the students may obtain the intensity versus wavelength curve described above for themselves. That is unnecessary for the purpose at hand, and may raise more questions than it answers for the students. A full description of the processes that give rise to the observed spectrum is usually not encountered in a college-level course until the junior year in a solid-state physics course.

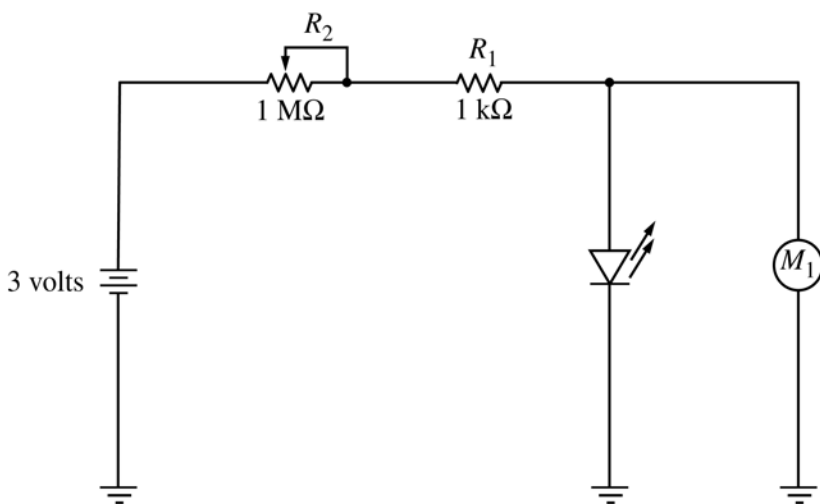


Figure 13.2

Another approach using a single LED is shown in Figure 13.2. The only change from the circuit in Figure 13.1 is the addition of R_2 , a $1\text{-M}\Omega$ variable resistor. In addition, the power supply should be a pair of D cells. The resistor R_1 is retained so that students cannot accidentally burn out the LED by turning the variable resistor to zero.

This experiment is best undertaken in a dark room. (Wire up the circuit before turning off the lights.) The variable resistor R_2 is adjusted until the LED barely glows. The potential V is read from the DMM, and the wavelength determined as above. It is best to turn the room lights up and adjust R_2 until the LED glows brightly before determining the wavelength. The reason for adjusting the brightness of the LED is to obtain a voltage reading that corresponds to the minimum energy required to generate a photon. While this technique reduces the error associated with the voltage measurement, the error associated with the measurement of the wavelength is still present.

After the voltage and wavelength data is acquired, the frequencies associated with the measured or guessed wavelengths are calculated. The voltages are plotted against the frequencies, and a best-fit straight line is drawn through the data. The slope of the straight line should equal h/e to within 10%. This is as well as one does with a commercial Planck's constant apparatus costing far more than the equipment described here. In addition, if the students do a least-squares fit of the data, they usually find that the deviation of the slope from the nominal value of h/e is less than the uncertainty associated with the slope.

LAB FOURTEEN

The Photoelectric Effect*

Introduction

This experiment involving the photoelectric effect provides the student with an excellent opportunity to investigate one of the primary pieces of evidence that was used to support quantum theory in the early 20th century. The textbook descriptions of the effect often gloss over the difficulties of carrying out the experiment. The photocurrents produced in the lab are usually less than a milliamp, and require a stable and sensitive amplifier to be detected. Here we present an inexpensive circuit that can be built for less than \$150 per lab setup that enables the students to investigate several different aspects of the photoelectric effect.

Theory

The photoelectric effect is covered in detail in most introductory textbooks that contain chapters on modern physics, but a brief review is given here. When a photon of energy hf is absorbed by an electron in a metal, the electron may escape the metal if the energy of the photon is greater than the work function W of the metal. If $hf > W$, then the electron acquires a kinetic energy K given by

$$K = hf - W \quad (14-1)$$

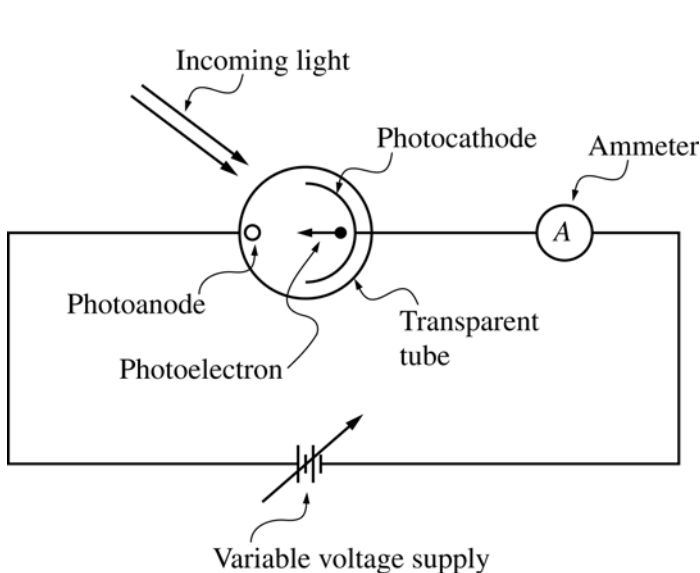


Figure 14.1

If the photocathode that emits these electrons is placed in a vacuum, the electrons can be attracted to a positively charged anode as shown in Figure 14.1. The ammeter A measures the current due to the electrons that are ejected by the photocathode. To give some idea of how small the current is, consider a 1 mW, 633 nm laser shining directly on the photocathode. If every photon ejected an electron upon striking the photocathode, the photocurrent would be approximately 500 microamps.

* This lab requires the teacher or students to construct some electronic apparatus. Teachers with little or no experience with electronics may wish to forego this lab, or to undertake it as an extended project with students.

If we now apply a negative potential to the photoanode, the photoelectrons are slowed as they approach it. We may increase the magnitude of the negative potential until no electrons have enough kinetic energy to reach the photoanode. The magnitude of the electric potential necessary to stop all photoelectrons from reaching the photoanode is the stopping potential V_{stop} . The most energetic photoelectrons have a kinetic energy K that is equal to the product of the charge of the electron e and the stopping potential V_{stop} . We may write Equation 14-1 as

$$eV = hf - W \quad (14-2)$$

We may illuminate the photocathode with light of a particular frequency and then measure the stopping potential. After repeating this procedure for several frequencies, we may then graph the stopping potential versus the frequency, and obtain a straight line with a slope h/e . The y -intercept of that straight line is equal to the work function of the metal.

Apparatus

A. The Electronics

A block diagram of the electronics used in this experiment is shown in Figure 14.2. The phototube may be forward-biased or reverse-biased. When the phototube is forward-biased, the

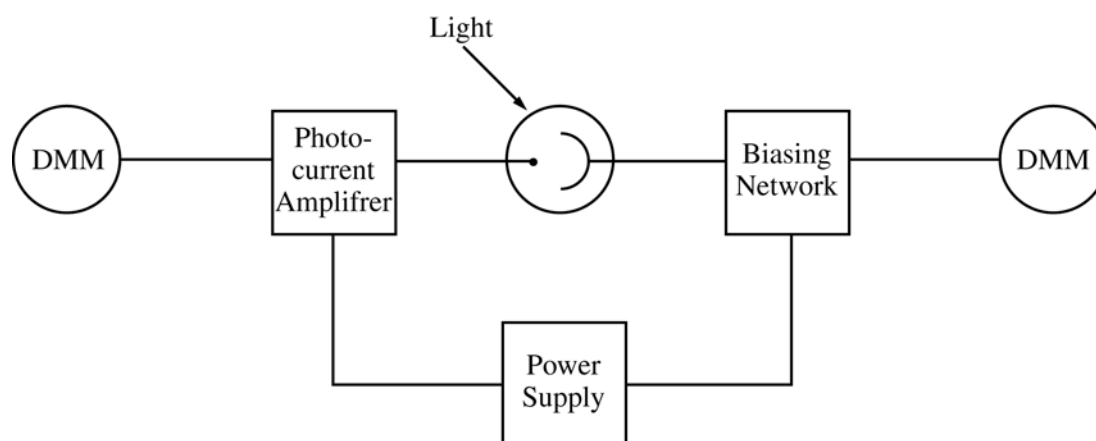


Figure 14.2

photocathode is electrically positive with respect to the photoanode. When the phototube is reverse-biased, the phototube is electrically negative with respect to the photoanode. Both configurations are used in this lab. The reverse-bias configuration is the configuration used to determine the stopping potential.

The photocurrent is measured by an operational amplifier (op amp) that is wired up as a transconductance amplifier, as shown in Figure 14.3. The choice of op amp is not critical, but it should be one that is stable over time with low noise. An OP-7 is a good choice, and any similar

op amp should also do well in this circuit. The output of the transconductance amp goes to a digital multimeter, used as a **voltmeter**. An output of one volt corresponds to a photocurrent of 1 microamp. The circuit construction may be done on a solderless breadboard. Wiring the circuit on a small piece of perf board and mounting it in a metal box may be preferable, as it reduces set-up time significantly. The op amps should be mounted in 8-pin DIP sockets, as soldering directly to the pins on the op amp may damage the devices.

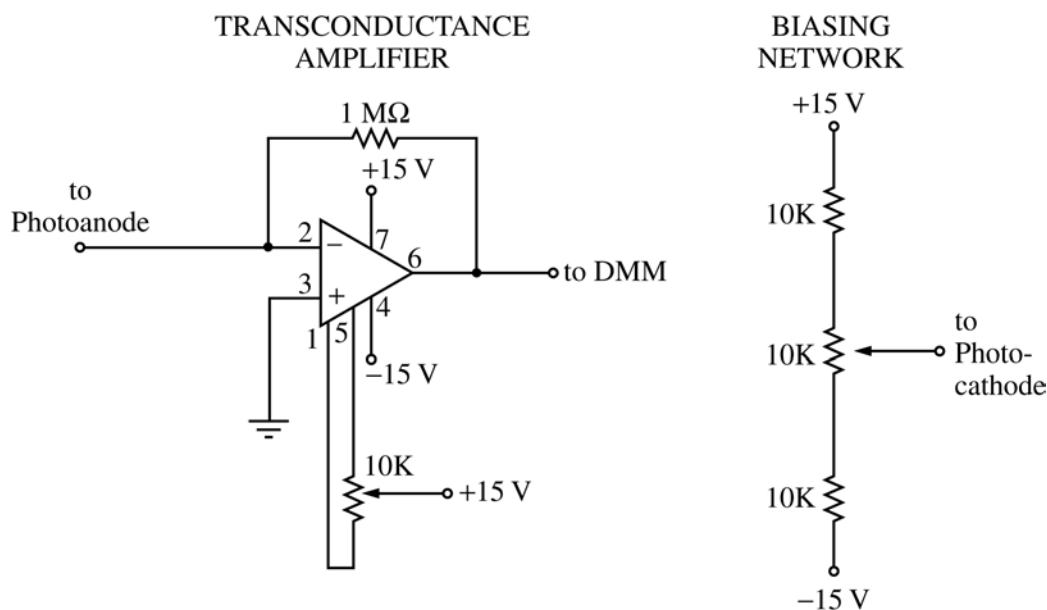


Figure 14.3

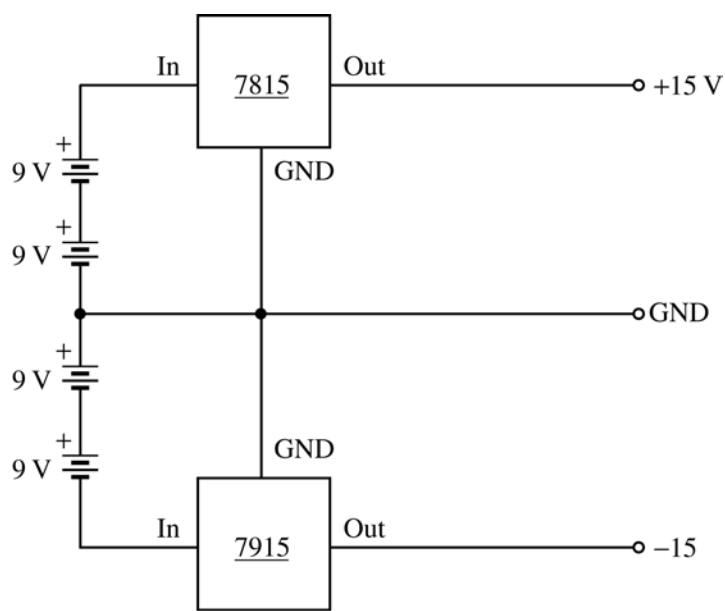


Figure 14.4

The power supply is a simple ± 15 -volt split supply, as shown in Figure 14.4 and 14.5. If you don't plan to mount the circuit in a metal box, the circuit shown in Figure 14.4 may be used. The disadvantage to the circuit shown in Figure 14.4 is that it uses four 9-volt batteries. The advantage is that it is safer than the circuit shown in Figure 14.5.

IF YOU USE THE CIRCUIT SHOWN IN FIGURE 14.5, YOU MUST MOUNT THE POWER

SUPPLY IN A GROUNDED METAL ENCLOSURE. USING 120VAC ON A SOLDERLESS BREADBOARD IS EXTREMELY HAZARDOUS, AND MAY RESULT IN SERIOUS INJURY OR DEATH. Given that, you may wonder why anyone would opt to use the circuit shown in Figure 14.5. The reason is that it does away with batteries, which have a nasty habit of going dead while you or the students are taking data, and it is cheaper to operate.

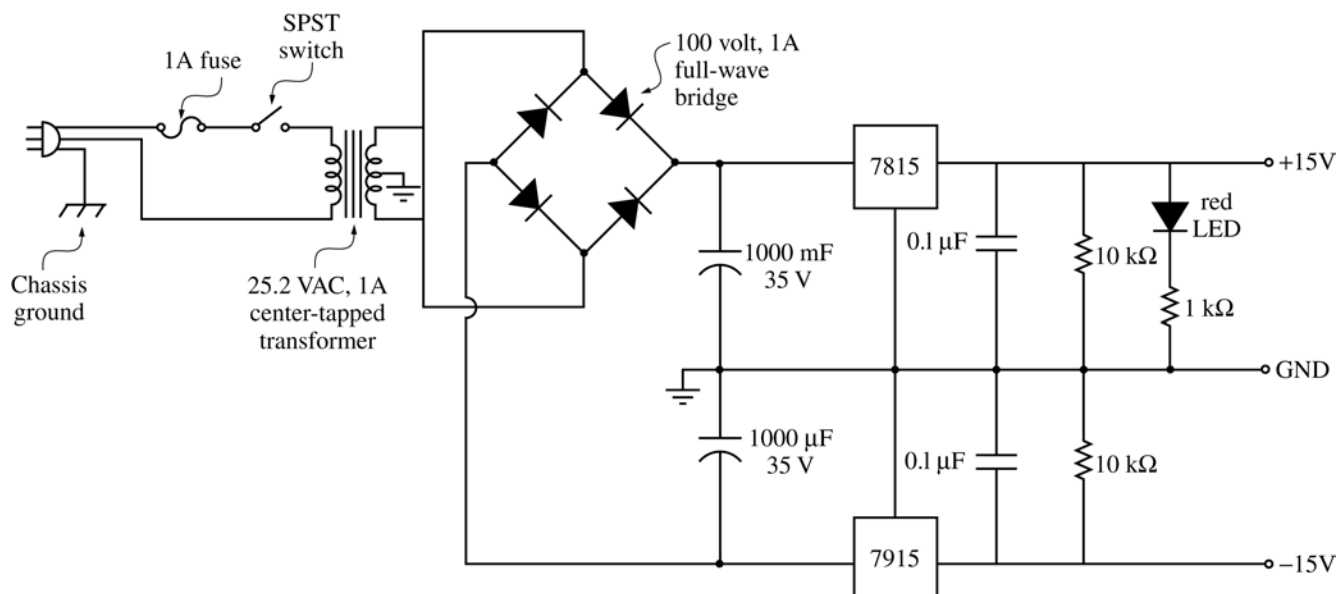


Figure 14.5

For all of the integrated circuit components used in this lab, it is imperative to follow the pin-out given in Figure 14.6. Please note that the pin-outs on the 7815 and the 7915 voltage regulators are different.

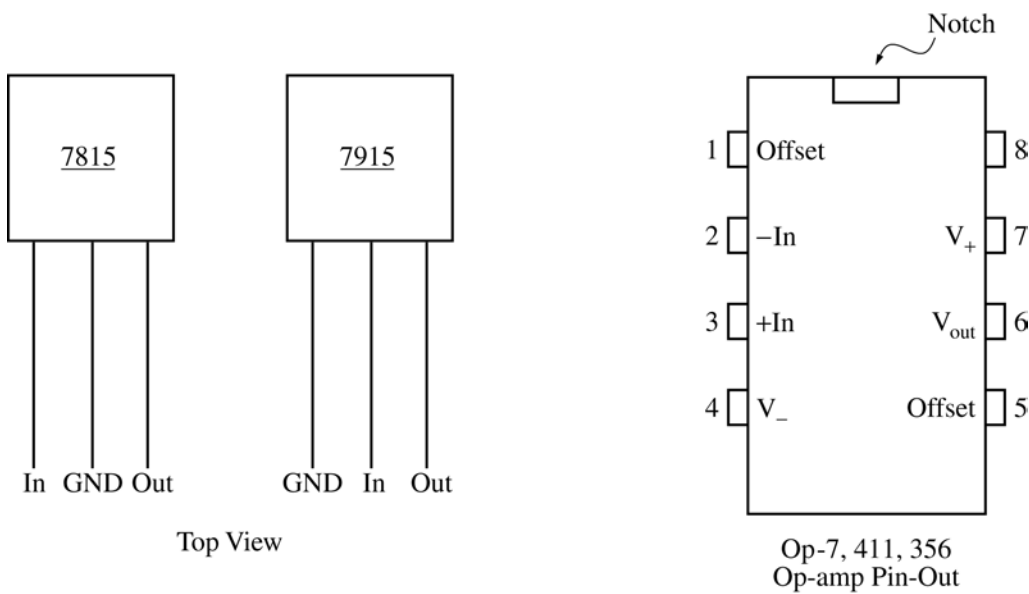


Figure 14.6

B. The Phototube

The phototube is a 1P39 mounted in a ceramic octal socket. One nice feature of the phototube is that it has a clear glass envelope, and students can easily see the photocathode (the large curved electrode) and the photoanode (the upright wire in the center of the tube). A pair of color-coded twisted leads runs from the ceramic socket to the amplifier.

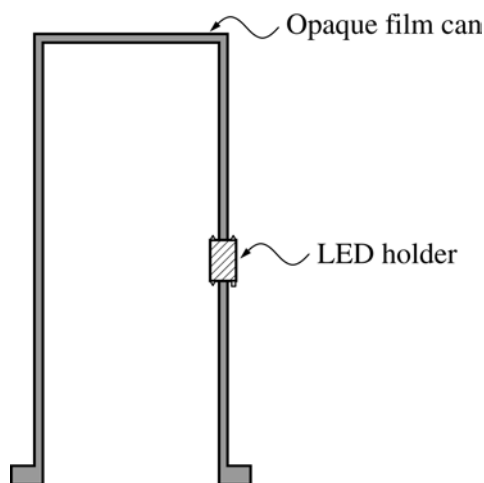


Figure 14.7

The easiest way to keep out stray light is by slipping an opaque plastic 35mm film canister over the phototube. Before slipping it over the tube, a $\frac{1}{4}$ inch hole should be drilled in the film can about halfway down the side of the canister. A plastic LED holder, available at most electronic parts dealers, is then placed in the hole so that an LED may be mounted to shine on the phototube, as in Figure 14.7.

The determination of the wavelength of the LEDs is described in the *Planck's Constant on the Cheap* experiment, and is not repeated here. Blue, green, yellow, red and infrared LEDs may be used.

The light from the 912-nm LEDs does not generate a photocurrent, as the energy of the infrared photons is less than the work function of the photocathode. Explaining this absence of photocurrent brings home to students one of the puzzling aspects of the photoelectric effect, that is, that no photocurrent is generated for light whose energy is an amount hf below the work function.

Experiment

The acquisition of the data is straightforward. Once the LED is inserted in the $\frac{1}{4}$ inch LED holder and the electronics are turned on, the photodiode should be forward biased to its maximum voltage. This should be around 5 volts. One DMM monitors the bias voltage, while the second DMM monitors the output of the transconductance amplifier. Remember that a one-volt output of the amplifier corresponds to a photocurrent of one microamp.

The bias voltage is decreased to zero in half-volt increments. At each increment the photocurrent is recorded. When the bias voltage reaches zero, the bias switch is thrown to reverse the bias on the phototube, and the procedure is repeated. The data exhibit a decrease, but it is not possible to find the stopping potential exactly using this method. It does allow the students to find the stopping potential to within a volt or so. Remember that the stopping potential is the bias voltage at which the photocurrent goes to zero.

Once the stopping potential is located approximately, the students should approach it in 0.1 volt increments from at least ± 1 volt away. For example, if it seems the stopping potential is 1.2 volts, the students should go to zero volts and increase the voltage 0.1 volt increments. As the stopping potential is approached, the output of the amplifier will fluctuate, making it difficult to find the point where the photocurrent is zero. If the photocurrent is plotted versus the bias voltage, a best-fit straight line to the data taken close to the stopping potential is one method of getting around this difficulty.

This procedure is then repeated for the other LEDs. Once the stopping potentials are found, they may be plotted versus the frequency of light emitted by the LEDs. This graph then yields h/e , and the work function of the photocathode.



Bristol Public Schools
Office of Teaching & Learning

DEPARTMENT: Business and Finance

COURSE: Computer Programming and Video Game Design

PREREQUISITES: None

Do you want to learn how video games are made? Do you have the best ideas that would make the next awesome video game “out there”? Then get off the couch and start developing your skills so you can unleash your creative genius on the video game universe. In this fast paced course students will learn the basics of video game programming and will start making video games that you and your friends can play on any PC. Course will involve work in computer programming and computer graphics. While there is no prerequisite coursework, strong computers skills are a must. Students who are not already “very proficient” in the use of computers should consider taking an introductory computer course such as Information Processing -1 first.

DEPARTMENT PHILOSOPHY:

The Business Department curriculum enables students to acquire and strengthen literacy, numeracy, decision-making and computer skills through a series of three coordinated course pathways: Accounting, Computer Information Systems and Business Management. Students will actively use technology as a tool to gather, analyze and communicate information, solve problems and make responsible, ethical decisions. Our focus will be to assist and encourage each student to use education to develop leadership, interpersonal and technological skills necessary for post-secondary, professional and personal success in a competitive global marketplace.

DEPARTMENT GOALS:

- Develop students' literacy and numeracy skills
- Encourage students to pursue advanced study in business and computer technology
- Employ instructional methods and interdisciplinary activities that stimulate student interest in business and computer technology
- Provide experiences for students to develop and demonstrate business-related knowledge and skills
- Engage students in real-world problem solving experiences
- Emphasize ethical business practices

STUDENT GOALS:

- Utilize literacy and numeracy skills in practical applications
- Develop an appreciation for lifelong learning and further education
- Exhibit effective communication, computation, critical thinking and decision-making skills
- Demonstrate knowledge and mastery of skills in business and computer technology
- Apply and adapt skills learned to different career and life situations
- Understand the legal and ethical aspects of business

INSTRUCTIONAL TOPICS FOR THE COURSE:

1. Introduction to Computer Programming
2. Genres of and Audiences for Video Games
3. The Design Cycle
4. Video Game Making Applications
5. Physical Laws That Affect Movement of Objects
6. Computer Graphics (2D) and Audio
7. Create Video Game Component and Simple Video Games
8. Create and Present Marketing Plans

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#1	Introduction to Computer Programming
Career and Technical Education Content Standard F. CIS - Programming and Application Development: Demonstrate the ability to code. Career and Technical Education Performance Standard F 13. Identify and explain programming structures. F 14. Apply design principles to programming tasks. Career and Technical Education MATH Standard M-3: DEVELOP STRATEGIES FOR COMPUTATION AND ESTIMATION USING PROPERTIES OF NUMBER SYSTEMS TO SOLVE PROBLEMS: 3.1 Select and use appropriate methods for computing to solve problem in a variety of contexts Common Core Standards (Gr. 11-12) Reading Standards For Literacy 4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics.	
Unwrapped Performance Standards	
Skills: Be able to: F 13) Identify and explain F 14) Use CATE/M 3.1 Solve numerical problems CCS/R 4) Determine	Concepts: Need to know about: programming structures. design principles in programming tasks. using correct methods in various contexts. the meaning of symbols, key terms and other words and phrases as used in context.
<u>Essential Questions</u> <i>Teacher's guiding questions:</i> • What skills are necessary in the professional world of video game development? • How has computer programming evolved over time? <u>Big Ideas</u> <i>Student's statements of enduring ideas:</i> • Many skills are necessary in professional game development, especially coding. • Object Oriented Programming (OOP) is in the forefront of programming.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
F 13) Identify and explain programming structures. F 14) Use coding concepts and processes in programming. CATE/M 3.1 Solve problems using numbers associated with programming. CCS/R 4) Determine the meaning of symbols, terms and concepts used in code programming.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Provide teacher consultation and individual assistance ○ Provide online instructional materials for independent learning	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Formative and summative assessments ○ Creation of programs using JavaScript

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#2 Genres of and Audiences for Video Games	
Career and Technical Education Content Standard A. CIS - Impact on Society: Assess the impact of information technology in a global society. Career and Technical Education Performance Standard A1. Describe the impact of technology on the knowledge and skills needed for success in the workplace. Common Core Standards (Gr. 11-12) Reading Standards For Literacy 2) Determine the central ideas or conclusions of a text; summarize complex concepts, processes or information presented in a text by paraphrasing them in simpler but still accurate terms. Common Core Standards (Gr. 11-12) Writing Standards For Literacy 4) Produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience.	
Unwrapped Performance Standards	
Skills: Be able to: A1) Describe CCS/R 2) Show an understanding CCS/W 4) Produce	Concepts: Need to know about: technology knowledge and skills needed for success. of the main ideas and conclusions of texts. clear and coherent writing as appropriate for task, purpose and audience.
Essential Questions <i>Teacher's guiding questions:</i> • What kinds of video games are there? Who do you think would be interested in playing (or not playing) any of them. • What makes a video game "appropriate" or not for different audiences? Who are those audiences? • How can we obtain and utilize feedback from others to help insure the quality and marketability of our projects? Big Ideas <i>Student's statements of enduring ideas:</i> • There are a number of basic of video game genres to suit a variety of audiences and purposes. • Different genres of game design lend themselves better to some audience interests and applications than others; the match of genre to player is important. • Soliciting and using feedback from others about project design, theme and implementation can both save production time and improve the quality and marketability of output.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
A1) Describe a variety of video game genres, and explain how video games and their technologies have evolved over time. CCS/R 2) Show an understanding of how various genres and themes lend themselves to certain kinds of audiences. CCS/W 4) Describe the elements of a "good game" and explain why they represent quality video game design.	○ Explain, present and demonstrate topics ○ Assign projects and activities ○ Engage students in reading, both in class and as homework ○ Question students to elicit participation and stimulate discussion ○ Engage students in research	○ Activities, assignments and projects ○ Informal in-process evaluation and feedback ○ Formative and summative assessments ○ Readings about different video game genres

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#2 The Design Cycle	
Career and Technical Education Content Standard F. CIS - Programming and Application Development: Demonstrate the ability to code.	
Career and Technical Education Performance Standard F14. Apply design principles to programming tasks.	
Common Core Standards (Gr. 11-12) Reading Standards For Literacy 2) Determine the central ideas or conclusions of a text; summarize complex concepts, processes or information presented in a text by paraphrasing them in simpler but still accurate terms. 4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics.	
Unwrapped Performance Standards	
Skills: Be able to: F 14) Use CCS/R 2) Show an understanding CCS/R 4) Determine	Concepts: Need to know about: design principles in programming tasks. of the main ideas and conclusions of texts. the meaning of symbols, key terms and other words and phrases as used in context.
Essential Questions <i>Teacher's guiding questions:</i> • What series of steps is appropriate in project design? • How can we make a sketch of the project for both planning and communication purposes? • What approaches to planning will allow us to both develop a vision of where the design is going, and break it up so multiple people can work on it? Big Ideas <i>Student's statements of enduring ideas:</i> • The design cycle allows us to plan, create, evaluate, and revise projects. • Storyboarding develops ideas in pre-production and helps us communicate them to others • Soliciting and using feedback from others about project design can both save time and improve quality.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
F 14) Use the design cycle and its principles in video game planning and development. CCS/R 2) Show an understanding of why project planning and results are improved by the use of the design cycle. CCS/R 4) Determine how design terms and concepts aid in the understanding the design cycle and how to use them in the planning of work.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Engage students in reading, both in class and as homework ○ Review and discuss test and quiz content in class ○ Teach visualization methods: making and sketching mental images ○ Provide students with graphic organizers ○ Establish timelines for work completion	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Formative and summative assessments ○ Creation of a storyboard and other design ideas

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#4 Video Game Making Applications	
Career and Technical Education Content Standard	
F. CIS - Programming and Application Development: Demonstrate the ability to code.	
Career and Technical Education Performance Standard	
F 13. Identify and explain programming structures. (recommended to power?)	
F 14. Apply design principles to programming tasks.	
Common Core Standards (Gr. 11-12) Reading Standards For Literacy	
4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics.	
Unwrapped Performance Standards	
Skills: Be able to:	Concepts: Need to know about:
F 13) Identify and explain	programming structures.
F 14) Use	design principles in programming tasks.
CCS/R 4) Determine	the meaning of symbols, key terms and other words and phrases as used in context.
Essential Questions	
<i>Teacher's guiding questions:</i>	
- What software is available as an interface to help streamline video game making, and what kinds of games can be made with them? - What skills are necessary to use game making programs to make video games?	
Big Ideas	
<i>Student's statements of enduring ideas:</i>	
- Video game making programs provide interfaces for making video games. There are 2D and 3D and video games, and an intermediate known as "2-1/2D". - Skills such as graphics, audio, story writing, testing, marketing and team organization play important roles in game development.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
F 13) Identify game making software and explain how it can be used to make video games. F 14) Use game making software to program video games using drag and drop and other object oriented programming (OOP) techniques. CCS/R 4) Show an understanding of symbols, terms and concepts used in object oriented programming (OOP) programming.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Provide teacher consultation and individual assistance ○ Use guided practice of tools and methods from written materials	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Creation of game components using video game software

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#5	Physical Laws That Affect Movement of Objects
Career and Technical Education Content Standard F. CIS - Programming and Application Development: Demonstrate the ability to code.	
Career and Technical Education Performance Standard F14. Apply design principles to programming tasks.	
Career and Technical Education MATH Standard M-3: DEVELOP STRATEGIES FOR COMPUTATION AND ESTIMATION USING PROPERTIES OF NUMBER SYSTEMS TO SOLVE PROBLEMS: 3.1 Select and use appropriate methods for computing to solve problem in a variety of contexts	
Common Core Standards (Gr. 11-12) Reading Standards For Literacy 4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics.	
Unwrapped Performance Standards	
Skills: Be able to: F 14) Use CATE/M 3.1 Solve numerical problems CCS/R 4) Determine	Concepts: Need to know about: design principles in programming tasks. using correct methods in various contexts. the meaning of symbols, key terms and other words and phrases as used in context.
Essential Questions <i>Teacher's guiding questions:</i> - How do the laws of physics apply to the development of video games? - How can a "digital" object be made to "look, feel and react" like real physical objects in the game?	
Big Ideas <i>Student's statements of enduring ideas:</i> - Objects in motion are governed by the laws of physics. - The way objects react to motion and collision in video games either enhances or detracts from the "realism" of games.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
F 14) Apply principles of physics and the interaction of physical objects to the interaction of digital "objects" in video game design. CATE/M 3.1 Solve numerical problems associated with the motion of digital objects and their interaction pursuant to game design. CCS/R 4) Determine the meaning of physics symbols, terms and words that describe and involve the way physical objects interact.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Engage students in reading, both in class and as homework ○ Teach visualization methods: making and sketching mental images	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Formative and summative assessments ○ Creation of game components using video game software

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#6 Computer Graphics (2D) and Audio	
Career and Technical Education Content Standard	
C.	CIS - Operating Systems and Utilities: Describe various types of operating systems and utilities.
D.	Input Technologies: Use various input technologies to enter and manipulate information appropriately.
Career and Technical Education Performance Standard	
C4.	Describe the process for managing folders and files.
D7.	Use a variety of input technologies to maximize productivity.
Unwrapped Performance Standards	
Skills: Be able to: C4) Describe D7) Use	Concepts: Need to know about: how to manage files and folders in an operating system. various input technologies productively.
Essential Questions <i>Teacher's guiding questions:</i> • How can we modify or create characters for game implementation? • How can we develop environments for game implementation? • What tools and techniques are helpful for the manipulation and design of graphics and audio game elements? Big Ideas <i>Student's statements of enduring ideas:</i> • There are a variety of methods for the creation and modification of graphics and audio. • Backgrounds are images on top of which the characters in a video game function. • Both commercial and freeware applications can be used for graphics and audio tasks.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
C4) Practice effective management of files and folders through the handling of graphics, audio and other project related files necessary to make video games. D7) Use a variety of input technologies while creating graphics, audio and other project related files for use in video games. Apply video game design principles in the development of graphics and audio content.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Provide written directions for assignments to be done in class and/or as homework ○ Use guided practice of tools and methods	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Creation of graphic and audio game components

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#7	Create Video Game Components and Simple Video Games
Career and Technical Education Content Standard	
F. CIS - Programming and Application Development: Demonstrate the ability to code.	
Career and Technical Education Performance Standard	
F 13. Identify and explain programming structures. F 14. Apply design principles to programming tasks.	
Common Core Standards (Gr. 11-12) Reading Standards For Literacy	
4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics.	
Unwrapped Performance Standards	
Skills: Be able to: F 13) Identify and explain F 14) Use CCS/R 4) Determine	Concepts: Need to know about: programming structures. design principles in programming tasks. the meaning of symbols, key terms and other words and phrases as used in context.
Essential Questions <i>Teacher's guiding questions:</i> - How can we make a simple video game with modest development costs that is fun to play? - How can we use a team approach to make larger video games? - What is the impact of missing deadlines of parts of a project? Big Ideas <i>Student's statements of enduring ideas:</i> - Video games are made in a step by step manner. - Well organized groups completing work simultaneously can achieve far more than individuals or poorly organized groups. - Missing deadlines stops progress of the group and wastes time, energy and money.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
F 13) Demonstrate an understanding of programming structures by making video games. F 14) Use design principles in programming and development tasks while making video games. CCS/R 4) Determine the meaning of symbols, terms and concepts used in video game programming. Apply skills in the use of graphics and audio in the design of video games.	○ Explain, present and demonstrate topics ○ Assign projects and activities that employ hands on learning ○ Provide teacher consultation and individual assistance ○ Teach visualization methods: making and sketching mental images ○ Use guided practice of tools and methods from written materials ○ Use formal and informal groups to foster teamwork and collaborative problem solving	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Creation of game components using video game software

SUBJECT	
Computer Programming and Video Game Design	
TOPIC	
#8 Create and Present a Marketing Plan	
Career and Technical Education Content Standard A. CIS - Impact on Society: Assess the impact of information technology in a global society. Career and Technical Education Performance Standard A1. Describe the impact of technology on the knowledge and skills needed for success in the workplace. Common Core Standards (Gr. 11-12) Reading Standards For Literacy 4) Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 text and topics. Common Core Standards (Gr. 11-12) Writing Standards For Literacy 4) Produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience.	
Unwrapped Performance Standards	
<u>Skills:</u> Be able to: A1) Describe CCS/R 4) Determine CCS/W 4) Produce	<u>Concepts:</u> Need to know about: technology knowledge and skills needed for success. the meaning of symbols, key terms and other words and phrases as used in context. clear and coherent writing as appropriate for task, purpose and audience.
<u>Essential Questions</u> <i>Teacher's guiding questions:</i> • What will it take for a video game product to be successful? • How can we interest investors in providing financial backing? <u>Big Ideas</u> <i>Student's statements of enduring ideas:</i> • A well designed video game that appeals to a target market is more likely to be successful. • The cost of development and potential revenue affect potential to make a profit.	

Bristol Public Schools
Business and Finance
Computer Programming and Video Game Design

LEARNING OBJECTIVES <i>Students will be able to:</i>	INSTRUCTIONAL STRATEGIES Based on our department philosophy for student learning Business and Finance teachers will:	Common Learning Experiences And Assessments Through these assessments/experiences students will demonstrate mastery of the learning objectives. Business and Finance teachers will assess and provide feedback to students regarding:
A1) Describe a target market for a video game design, and explain how the game designed will impact that market en-route to becoming a commercial success. CCS/R 4) Determine the meaning of symbols, terms and concepts used in marketing for use in a product plan for a video game. CCS/W 4) Produce a clear and concise written marketing plan to for a financing and commercial development audience for the purpose of continuing the development of the video game as a business venture.	○ Explain, present and demonstrate topics ○ Assign projects and activities ○ Provide teacher consultation and individual assistance ○ Use formal and informal groups to foster teamwork and collaborative problem solving ○ Engage students in research	○ Activities, assignments and projects ○ Authentic performance assessments, when applicable ○ Informal in-process evaluation and feedback ○ Formative and summative assessments ○ Creation of a marketing plan for the video game.



**Bristol Public Schools
Office of Teaching & Learning**

DEPARTMENT: Science

COURSE: Environmental Science

PRE-REQUISITE: Must have "70" average in Biology

COURSE DESCRIPTION:

This course engages the student through investigations of relevant environmental issues. The course utilizes the "eight practices of science" to understand ecological interactions, biomes, energy resources, land and water resources, and management of the environment. Field trips and local environmental work will be an integral part of the course.

DEPARTMENT GOALS:

Through a planned, sequenced curriculum, Bristol Public Schools strives to educate each student in conjunction with the Common Core Science Curriculum Framework. Students should be able to demonstrate concepts and skills in the following areas:

- Understand and apply the core concepts of life, earth, and physical science;
- Recognize the interactions among science, technology and society;
- Interpret and evaluate information;
- Collaborate to solve problems through the scientific method;
- Use mathematics to make sense of data and to solve problems;
- Use technology and search scientific databases to understand current, global issues; and
- Communicate orally and in writing: pose questions, summarize information, construct meaning, support conclusions, and apply concepts to unfamiliar situations.

DEPARTMENT PHILOSOPHY:

The science program must provide students with core science concepts and skills to lead to a deeper understanding and appreciation of the complex world in which we live. With these key ideas, students will be able to develop explanations for natural phenomena and apply experimental procedures to collect and analyze data to answer their own questions. As students reason logically, they will use an inquiry approach to science, which includes hands-on laboratory experiences. Further, the program should expose students to careers in science, technology, and engineering while engaging them in the role science plays in potentially solving challenges in this century. In the science program students will read and write with a purpose and critically evaluate information.

PHILOSOPHY OF INSTRUCTION:

Based on our department philosophy and goals, science teachers will:

- Provide a safe, effective and hands-on learning environment. Science safety procedures will be established and practiced in all laboratories and classroom/laboratory settings;
- Use a variety of source material, including the BOE approved textbook, to reinforce and explore curriculum concepts and skills;
- Use an inquiry approach to foster student thinking, promote questioning, and spark interest within units;
- Provide a variety of models and demonstrations to allow students to "experience" scientific concepts;
- Facilitate in depth exploration, discussion and application of concepts so students understand how scientific knowledge is created, experienced, validated, and communicated
- Structure learning experiences that encourage collaborative problem solving and application of concepts and skills to new situations;
- Tailor instruction to meet the needs of a variety of learners based on student readiness, interest, and learning style.

The instructional strategies recommended in our resource document are specific examples of these expectations in practice. They serve as a starting point for planning and implementing instruction that will develop our students as thinkers. Teachers will modify, revise, and create new instructional strategies and activities as they continue to grow professionally and as they develop an understanding of each student's unique strengths, weaknesses, and interests.

PHILOSOPHY OF ASSESSMENT:

Based on our department philosophy and goals, science teachers will:

- Use formal and informal assessment throughout units. Assessment will be ongoing and frequent;
- Analyze results and shift instruction based on the results;
- Provide feedback for students; and
- Use scoring rubrics and establish anchor papers.

In order to understand the strengths and weaknesses of our students and to be able to ensure that each student develops into a scientifically literate individual, science teachers will provide feedback to students about the following:

- Experimental design
- Laboratory reports: interpret/analyze data to form conclusions
- Models and concept maps which demonstrate understanding and application of scientific concepts
- Constructed response writing: explain, elaborate, apply and evaluate
- Performance based assessments, including STS (Science, Technology, and Society) activities, with incorporation of technology
- Problem solving

INSTRUCTIONAL TOPICS FOR THIS 181 DAY EXPERIENCE INCLUDE:

1. Introduction to Environmental Science
2. Ecosystems
3. Populations
4. Land use
5. Water
6. Air
7. Energy
8. Waste

Standards for this curriculum were developed and published by the North American Association for Environmental Education as part of the National Project for Excellence in Environmental Education: Guidelines for Learning K-12

Content Standards

Culture – Learners understand cultural perspectives and dynamics and apply their understanding in context.

Global Connections – Learners are able to analyze global social, cultural, political, economic, and environmental linkages.

Human/environment interactions – Learners understand that humans are able to alter the physical environment to meet their needs and that there are limits to the ability of the environment to absorb impacts or meet human needs.

Performance Standards

A. Describe and compare historical and contemporary societal strategies for adapting to environmental or social change while preserving and transmitting culture. For example, describe ways resource-dependent communities (those whose economies traditionally relied on activities such as mining or timber harvest) work to maintain their identities in the face of mine closures or declining timber harvests.

B. Evaluate the connections among interests, decisions, and actions taken at the individual, community, regional, national, and global levels. Consider their effect on global issues such as human rights, economic development, health, resource allocation, and environmental quality. For example, examine the influence of factors such as consumer preferences, U.S. foreign policy, international treaties and governing bodies, international nongovernmental organizations, and corporate operations on agricultural practices in developing nations.

C. Evaluate the cumulative effects of human actions on a specific species or environmental system, such as a stream or a watershed.

D. CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.

E. CCSS.ELA-LITERACY.WHST.11-12.1.D. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

F. CCSS.ELA-LITERACY.SL.11-12.3 Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

Unwrapped Performance Standards**Skills:****Concepts:**

Describe

Compare

Evaluate

Consider

Evaluate

Historical and contemporary strategies for adapting to environmental or social change

Historical and contemporary strategies for adapting to environmental or social change

Connections among interests, decisions, and actions taken at the individual, community, regional, national, and global levels

Their effect on global issues

Cumulative effects of human actions on a specific species or environmental system

Unwrapped Performance Standards

Skills:	Concepts:
Determine	The central ideas or information of a primary or secondary source
Provide	An accurate summary that makes clear the relationships among the key details and ideas.
Establish	A formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing
Maintain	A formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing
Evaluate	A speaker's point of view, reasoning, and use of evidence.

Learning Plan

Essential Question:	Big Idea:	
How can humans solve environmental problems?	Humans are responsible for environmental problems and must solve them using an interdisciplinary approach.	
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Evaluate why we have environmental problems Analyze options for solving current environmental problems Explain sustainability and why it's a goal of environmental science Evaluate their contribution to environmental issues	- Ask questions and define environmental problems - Facilitate class discussion and engage students in arguing from evidence** - Provide research opportunities using current technology - Provide opportunities for collaborative learning** - Provide opportunities to analyze and interpret data - Provide opportunities to use mathematics and computational thinking	Performance Assessment: Decision-making activity - Public vs private resources Summative Unit assessment Ecological Footprint Case Study on Current Environmental Event

Content Standards

Organisms, populations, and communities – Learners understand basic population dynamics and the importance of diversity in living systems

Systems and connections – Learners understand the living environment to be comprised of interrelated, dynamic systems

Environmental issues – Learners are familiar with a range of environmental issues at scales that range from local to national to global. They understand that these scales and issues are often linked.

Performance Standards

A. Explain how diversity of characteristics among organisms of a species increases the likelihood of the species surviving changing environmental conditions.

B. Describe how adding a species to, or removing one from, an ecosystem may affect other organisms and the entire system.

C. Evaluate a range of costs and benefits of particular policies that affect the environment. For example, consider the effects of free trade agreements on the ability of signatory nations to protect the environment, or examine the effects of programs for trading "pollution credits" among companies.

D. CCSS.ELA-LITERACY.RST.11-12.3

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

E. CCSS.ELA-LITERACY.WHST.11-12.2.B

Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

Unwrapped Performance Standards

Skills:	Concepts:
Explain	How diversity of characteristics among organisms of a species increases the likelihood of the species surviving changing environmental conditions.
Describe	How adding a species to, or removing one from, an ecosystem may effect other organisms and the entire system.
Evaluate	Range of costs and benefits of particular policies that affect the environment.
Follow	A complex multistep procedure
Analyze	Results based on explanations in the text
Develop	Topics thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples

Learning Plan		
Essential Question:		Big Idea:
How are humans impacting the biosphere?		Human activity has significant impacts on biosphere
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Explain how abiotic and biotic factors contribute to ecosystem health Analyze human impact on ecosystems Determine the importance of biodiversity	• Ask questions and define environmental problems • Facilitate class discussion and engage students in arguing from evidence • Provide research opportunities using current technology • Provide opportunities for collaborative learning** • Provide opportunities to analyze and interpret data** • Provide opportunities to use mathematics and computational thinking	Quadrant Study Summative Unit Assessment

Content Standard	
Organisms, populations, and communities – Learners understand basic population dynamics and the importance of diversity in living systems	
Performance Standards	
A. Discuss some of the ways in which populations can change over time, using ideas such as cyclic fluctuations, equilibrium, and coupled oscillations. Evaluate influences on population growth rate, including reproductive strategies and resource limitations. B. CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. C. CCSS.ELA-LITERACY.WHST.11-12.2.E Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic). D. CCSS.ELA-LITERACY.SL.11-12.4 Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.	

Unwrapped Performance Standards	
Skills:	Concepts:
Discuss	Ways in which populations can change over time
Evaluate	Influences on population growth rate
Cite	Specific textual evidence to support analysis of science and technical texts
Provide	A concluding statement or section that follows from and supports the information or explanation provided
Present	Information, findings, and supporting evidence, conveying a clear and distinct perspective

Learning Plan		
Essential Questions:		Big Idea:
Why do populations trend? How do these trends impact the environment?		Population trends are based on interrelated and complex factors.
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Analyze factors that change populations Predict population trends based on data Analyze how populations impact the environment/resources	• Ask questions and define environmental problems • Facilitate class discussion and engage students in arguing from evidence** • Provide research opportunities using current technology • Provide opportunities for collaborative learning • Provide opportunities to analyze and interpret data** • Provide opportunities to use mathematics and computational thinking • Provide opportunities to engage in arguments from evidence**	Population Activity(s) Summative Unit Assessment Case study: developed vs. developing countries

Content Standard

Human/environment interactions – Learners understand that humans are able to alter the physical environment to meet their needs and that there are limits to the ability of the environment to absorb impacts or meet human needs. Learners understand “place” as humans endowing a particular part of the Earth with meaning through their interactions with that environment.

Performance Standards

- A. Evaluate the cumulative effects of human actions on a specific species or environmental system, such as a stream or a watershed.
- B. Analyze how places change over time as the physical environment changes and as human use and perceptions change. For example, examine the effects of automobiles and the interstate highway system on different places.
- C. CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- D. CCSS.ELA-LITERACY.WHST.11-12.1.B Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.
- E. CCSS.ELA-LITERACY.SL.11-12.1.B Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

Unwrapped Performance Standards

Skills:	Concepts:
Evaluate	Cumulative effects of human actions on a specific species or environmental system
Analyze	How places change over time as the physical environment changes and as human use and perceptions change
Determine	The meaning of symbols, key terms, and other domain-specific words and phrases
Develop	Claim(s) and counterclaims fairly and thoroughly
Work	With peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

Learning Plan		
Essential Question:		Big Idea:
How do humans use of land impact the environment?		Human land use activities positively and negatively impact the environment.
Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Determine how humans use land for mining, forestry, agriculture, urbanization, open space, etc. Analyze the impacts of human land use. Determine the land-use practices that promote conservation/sustainability of resources.	• Ask questions and define environmental problems* • Facilitate class discussion and engage students in arguing from evidence* • Provide research opportunities using current technology • Provide opportunities for collaborative learning* • Provide opportunities to analyze and interpret data* • Provide opportunities to develop and use models* * NGSS – Science and Engineering practices	Soil test activity: physical and chemical properties of soil. Formative Land use/planning activity Summative Unit Assessment

Content Standards

Processes that shape the Earth – Learners understand the major physical processes that shape the Earth. They can relate these processes, Especially those that are large-scale and longterm, to characteristics of the Earth

Human/environment interactions – Learners understand that humans are able to alter the physical environment to meet their needs and that there are limits to the ability of the environment to absorb impacts or meet human needs.

Performance Standards

A. Describe possible relationships between surface water and ground water. For example, create a model or a cross-sectional drawing that shows surface and groundwater flows in a local drainage. Explain why surface and ground water are related in these ways.

Evaluate the cumulative effects of human actions on a specific species or environmental system, such as a stream or a watershed.

B. CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

C. CCSS.ELA-LITERACY.WHST.11-12.1.B Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

Unwrapped Performance Standards

Skills:	Concepts:
Describe	Relationships between surface water and ground water
Explain	Why surface and ground water are related
Evaluate	Cumulative effects of human actions on a specific species or environmental system
Synthesize	Information from a range of sources
Resolve	Conflicting information when possible
Develop	Claim(s) and counterclaims fairly and thoroughly

Learning Plan		
Essential Question:		Big Idea:
How are water resources impacted?		Human activities greatly impact water resources.
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Identify distribution and use of water resources on Earth (fresh and marine) Explain how humans impact water resources Determine how humans can promote sustainability/conservation of water resources Relate water quality to human health	• Ask questions and define environmental problems • Facilitate class discussion and engage students in arguing from evidence* • Provide research opportunities using current technology* • Provide opportunities for collaborative learning • Provide opportunities to analyze and interpret data* • Provide opportunities to use mathematics and computational thinking* • Provide opportunities to obtain, evaluate, and communicate information ** * NGSS-Science and Engineering Practices ** Common Core Standard	Water quality tests using Vernier probes Summative Water Unit Assessment

Content Standards

Processes that shape the Earth – Learners understand the major physical processes that shape the Earth. They can relate these processes, Especially those that are large-scale and long-term, to characteristics of the Earth

Human/environment interactions – Learners understand that humans are able to alter the physical environment to meet their needs and that there are limits to the ability of the environment to absorb impacts or meet human needs.

Performance Standards

A. Relate different types of climate to processes such as the transfer of heat energy, cloud formation, wind and ocean currents, atmospheric circulation patterns, and the cycling of water. Explain how positive feedback loops can affect climate.

B. Explain the dynamic relationship between greenhouse gases, solar energy absorption and radiation, and climate.

C. Analyze specific examples of environmental change in terms of qualitative and quantitative costs and benefits for different groups of people and specific species or ecosystems. For example, evaluate the effect of sea level rise and other possible impacts of climate change.

D. CCSS.ELA-Literacy.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

E. CCSS.ELA-Literacy.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

F. CCSS.ELA-Literacy.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

G. CCSS.ELA-Literacy.W.11-12.1e Provide a concluding statement or section that follows from and supports the argument presented.

Unwrapped Performance Standards

Skills:	Concepts:
Relate	Different types of climate to processes
Explain	Positive feedback loops
Explain	Relationship between greenhouse gases, solar energy absorption and radiation, and climate
Analyze	Environmental change in terms of qualitative and quantitative costs and
Determine	Benefits for different groups of people and specific species or ecosystems meaning of symbols, key terms, and other domain-specific words and phrases

Unwrapped Performance Standards	
Skills:	Concepts:
Evaluate	Hypotheses, data, analysis, and conclusions
Integrate	Multiple sources of information
Evaluate	Multiple sources of information
Provide	Concluding statement in support of argument presented

Learning Plan		
Essential Question:	Big Idea:	
What human activities can have global impacts?	Human interactions with atmosphere can have global impacts.	
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Identify characteristics of the atmosphere Explain human activities impact air quality Analyze causes and impacts of climate change Propose solutions to address air quality issues Relate air quality to human health	Ask questions and define environmental problems* Facilitate class discussion and engage students in arguing from evidence* Provide research opportunities using current technology* Provide opportunities for collaborative learning Provide opportunities to analyze and interpret data* Provide opportunities to obtain, evaluate, and communicate information ** Provide opportunities to use mathematics and computational thinking* *NGSS – Science and Engineering Practices ** Common Core Standard	Formative air quality activity with Vernier probes Summative air quality assessment Climate change activity

Content Standards

Energy – Learners apply their knowledge of energy and matter to understand phenomena in the world around them.

Human/environment interactions – Learners understand that humans are able to alter the physical environment to meet their needs and that there are limits to the ability of the environment to absorb impacts or meet human needs.

Resources – Learners understand that the importance and use of resources change over time and vary under different economic and technological systems.

Performance Standards

A. Compare different means of generating electricity (such as coal-burning plants, nuclear reactors, wind, geothermal, and hydropower) in terms of the transformation of energy among forms, the relationship of matter and energy, and efficiency/production of heat energy.

B. Evaluate ways in which technology has changed humans' ability to alter the environment and its capacity to support humans and other living organisms. Consider technologies that have had impacts learners see as positive, as well as negative.

C. Describe how changes in technology alter the use of resources. Illustrate with examples such as the ability to harvest timber on steep slopes using helicopters or building technologies that incorporate nontraditional or recycled materials, or use of renewable energy resources.

D. CCSS.ELA-Literacy.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

E. CCSS.ELA-Literacy.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

F. CCSS.ELA-Literacy.W.11-12.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

Unwrapped Performance Standards

Skills:	Concepts:
Compare	Different means of generating electricity in terms of the transformation of energy among forms, the relationship of matter and energy, and efficiency/production of heat energy.
Describe	How changes in technology alter the use of resources
Evaluate	Ways in which technology has changed humans' ability to alter the environment and its capacity to support humans and other living organisms.
Consider	Technologies that impact learners positively, and negatively.

Unwrapped Performance Standards

Skills:	Concepts:
Determine	Meaning of symbols, key terms, and other domain-specific words and phrases
Synthesize	Information from a range of sources
Use	Technology
Produce, publish, and update	Writing products

Learning Plan

Essential Question:	Big Idea:	
How will global energy demands met sustainably?	With advanced technology and alternative energies, our global energy demands will be met sustainably.	
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Compare and contrast methods of energy production Analyze costs and benefits of global energy usage Propose sustainable and efficient solutions to meet energy demands	• Ask questions and define environmental problems* • Facilitate class discussion and engage students in arguing from evidence* • Provide research opportunities using current technology* • Provide opportunities for collaborative learning • Provide opportunities to analyze and interpret data* • Provide opportunities to obtain, evaluate, and communicate information ** • Provide opportunities to use mathematics and computational thinking* *NGSS – Science and Engineering Practices ** Common Core Standard	Summative energy unit assessment Performance higher level (DOK-4) project on renewable/alternative energy resources Energy source comparison activities

Content Standards

Resources – Learners understand that the importance and use of resources change over time and vary under different economic and technological systems.

Environmental issues – Learners are familiar with a range of environmental issues at scales that range from local to national to global. They understand that these scales and issues are often linked.

Performance Standards

A. Explain differences in the consumption of resources among nations using factors such as population size, cultural practices, dependence on fossil fuels, and varied geographic or economic distribution of resources.

B. Identify ways in which various resources can be recycled and reused. Evaluate the viability of recycling based on economic and technological factors, spatial variables such as distance from recycling facility to markets, and possible future developments. For example, discuss factors that influenced the development of the steel or plastics recycling industry in the United States.

C. Identify links among issues, for example the relationships among traffic congestion, poor air quality, and suburban sprawl. Explain key relationships among technological, social, ecological, economic, and other aspects of issues.

D. CCSS.ELA-Literacy.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

E. CCSS.ELA-Literacy.W.11-12.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

F. CCSS.ELA-Literacy.W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Unwrapped Performance Standards

Skills:	Concepts:
Explain Identify Evaluate	Differences in the consumption of resources Ways in which various resources can be recycled and reused The viability of recycling based on economic and technological factors, spatial variables
Identify Explain	Links among issues Key relationships among technological, social, ecological, economic, and other aspects of issues
Determine	Meaning of symbols, key terms, and other domain-specific words and phrases

Unwrapped Performance Standards

Skills:	Concepts:
Use Produce, publish, and update	Technology Writing products

Learning Plan

Essential Question:	Big Idea:	
How can humans manage their waste?	Waste is best managed by taking into account technological, social, ecological, economic, and other needs of a society.	
Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, science teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Science teachers will assess and provide feedback to students about the following:
Analyze patterns of consumption Analyze processes to manage waste Propose solutions to reduce impact of human waste	• Ask questions and define environmental problems* • Facilitate class discussion and engage students in arguing from evidence* • Provide research opportunities using current technology* • Provide opportunities for collaborative learning • Provide opportunities to analyze and interpret data* • Provide opportunities to obtain, evaluate, and communicate information ** • Provide opportunities to use mathematics and computational thinking* • *NGSS – Science and Engineering Practices • ** Common Core Standard	Field trip to waste facility and/or recycling facility Student self assessment on resource consumption Summative waste unit assessment



Bristol Public Schools Office of Teaching & Learning

DEPARTMENT: World Languages

COURSE: French 3

COURSE DESCRIPTION:

French 3 continues the content of the spoken language for listening comprehension and speaking, but the vocabulary and style of the written language are introduced to develop the reading and writing skills. Students receive training in guided literary analysis and composition such as summaries, character sketches, and original dialogue.

PREREQUISITES: French 2

DEPARTMENT PHILOSOPHY: Our primary goal is to help all students develop linguistic proficiency and cultural sensitivity in a second language of their choice.

We believe that all students can benefit from second language instruction. We recognize that not everyone learns at the same rate or in the same way; nevertheless, we believe that all students should have the opportunity to acquire language proficiency to a degree commensurate with their individual abilities.

In the 21st century, the need for effective communication and sensitivity to other cultures has become even more important. We believe that the study of more than one language is essential to meeting these global needs.

DEPARTMENT GOALS:

Through a planned, sequential curriculum, Bristol Public schools strives to educate each student in conjunction with the State Standards for World Languages education. Students should be able to demonstrate skills and knowledge in each of the following standards:

- ◆ Communicate in at least one language other than English;
- ◆ Gain knowledge and understanding of other cultures;
- ◆ Make connections with other areas of study and acquire information;
- ◆ Understand the nature of language and cultures through comparisons; and
- ◆ Participate in multilingual communities within a variety of contexts.

COURSE GOALS:

Academic and Accelerated Objectives:

Standards are taught in academic and accelerated classes. The coursework is differentiated in content, teaching process, and student products, as seen in lesson objectives, assessments, pacing and performance, with an expectation that accelerated students speak and read with greater independence and fluency. Accelerated students are expected to meet all objectives for the course as well as those that go beyond the academic level and are printed in **bold** and *italicized*. Differentiation strategies, assessments and activities for accelerated students are also written in **bold** and *italicized*. Essential questions and learning objectives align by categorization (i.e. culture-related essential questions are aligned with culture-related learning objectives)

World Languages: French Level 3

TOPIC: ECOLOGY

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
CONTENT STANDARD 2: Communication (Interpretive Mode)
CONTENT STANDARD 3: Communication (Presentational Mode)
CONTENT STANDARD 4: Culture
CONTENT STANDARD 5: Connections (Interdisciplinary Mode)
CONTENT STANDARD 6: Connections (Interdisciplinary Mode)
CONTENT STANDARD 7: Comparisons Among Languages
CONTENT STANDARD 8: Comparisons Among Cultures
CONTENT STANDARD 9: Communities

1.3.1 Exchange information about current and past events, as well as aspirations in their personal lives and the lives of their friends, families and others within their community.

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.4 Work in groups to develop solutions to problems that are of contemporary or historical interest in both the target and their native cultures.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest.

2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources.

2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles.

2.2.6 Begin to make informed hypotheses about the meaning of unfamiliar, more complicated passages in the target language, based on contextual clues.

3.2.1 Make brief presentations to their class in the target language on topics of personal interest or topics that have been studied in other subject areas.

4.3.1 Identify and analyze products and practices of the target culture (e.g., social, economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

4.3.2 Identify, experience or read about, and discuss expressive forms of the culture, including but not limited to literature, periodicals, films, television, websites and the fine arts, in order to explore their effects on the larger community.

4.3.4 Identify, discuss and analyze various patterns of behaviors or interactions that are typical of the target culture.

4.3.5 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the target culture.

5.2.2 Acquire more detailed information from a variety of sources in the world language classroom and integrate it with other school subjects, comparing and evaluating the similarities and differences in information.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

5.3.4 Use new information and perspectives gained through world language study to expand their personal

World Languages: French Level 3

TOPIC: ECOLOGY

knowledge and interdisciplinary connections.

6.3.1 Use multiple media resources to analyze aspects of the target culture(s) and apply their knowledge to new situations.

7.2.4 Expand comprehension strategies to predict outcomes and make comparisons.

7.3.1 Analyze various elements of the target language (such as time or tense), and compare and contrast them with comparable linguistic elements in English.

7.3.2 Evaluate the style of a communicative interaction in the target language.

8.3.2 Compare and contrast the treatment of current issues across cultures by drawing on authentic texts.

8.3.3 Analyze how other cultures view the role of the United States in the world arena.

8.3.4 Use new information and perspectives to compare and contrast their experiences with those of their peers in the target culture(s).

8.3.5 Use new and evolving information and perspectives to demonstrate understanding of the similarities and differences across cultures.

8.3.6 Use new and evolving information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

9.3.1 Communicate with members of the target culture and interpret information regarding topics of personal, community or world interest.

9.3.4 Use various media from the target language and culture for personal enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

1.3.1, 1.3.3, 1.3.4, 1.3.7, 2.2.1, 2.2.3, 2.2.5, 2.2.6, 3.2.1, 4.3.1, 4.3.2, 4.3.4, 4.3.5, 5.2.2, 5.3.1, 5.3.4, 6.3.1, 7.2.4, 7.3.1, 7.3.2, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 8.3.6, 9.2.7, 9.3.1, 9.3.4

Common Core State Standards for English Language Arts

The Common Core Standards are written for instruction in English; students will strengthen and reinforce their understanding of such skills in English by mastering some of the following standards in French:

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

WRITING: W

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI 6 Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

W 4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W 5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 9–10 on page 54.)

W 6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

W 9b Apply *grades 11–12 Reading standards* to literary nonfiction (e.g., "Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and

World Languages: French Level 3

TOPIC: ECOLOGY

sufficient; identify false statements and fallacious reasoning”).

W 10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

SL 1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grades 11-12 topics, texts, and issues*, building on others’ ideas and expressing their own clearly and persuasively.

SL 1a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well reasoned exchange of ideas.

SL 1b Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

SL 1c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

SL 1d Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL 3 Evaluate a speaker’s point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

L1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

L 2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 2b Spell correctly.

L 3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

L 4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on *grades 11–12 reading and content*, choosing flexibly from a range of strategies.

L 4a Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., *conceive, conception, conceivable*).

L4 c Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

L 4d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understating of figurative language, word relationships, and nuances in word meanings.

L 5b Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

World Languages: French Level 3	
TOPIC: <u>ECOLOGY</u>	
UNWRAPPED PERFORMANCE STANDARDS	
<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Exchange	Information (ecology, environment, nature, conservation)
Describe	Activities (preserving and destroying the environment)
Discuss	Environment and surroundings
Compare and contrast	People, places and things (nouns)
Use	Subjective and impersonal expressions
Identify	National parks
Comprehend	Conversations (environmental)
Comprehend	Main ideas (listening)
Develop	Logical arguments
Create	Writing samples
Apply	Concepts (subjunctive rules and usage)
Use	Multimedia sources
Exhibit	Awareness of audience (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of behavior (environmental attitude)
Analyze	Authentic cultural experiences
Evaluate	Cultural practices
Formulate	Conclusions (culture)

World Languages: French Level 3

TOPIC: ECOLOGY

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>ECOLOGY</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. What do I need to know to be able to talk about ecology and the environment? B. How do I talk about pollution and what needs to be done to prevent or curb it? C. How do I use demonstrative pronouns to refer to something that has already been mentioned? D. How do I speak subjectively? E. How do I use impersonal expressions of opinion to discuss my feelings? F. How do I discuss nature and animals? G. How do I express will and emotion? H. What do I need to know to be able to compare nouns?	Communication: A. Identify and demonstrate command of vocabulary related the ecology and the environment. B. Discuss and write about the causes and effects of pollution. C. Discuss means and ways of preventing and curbing pollution. D. Replace already mentioned nouns with demonstrative pronouns according to the gender and number of the noun. E. Use the subjunctive mood/tense to talk about my subjective feelings towards events and actions. F. Use impersonal expressions of opinion coupled with the subjunctive tense to express feelings. G. Identify vocabulary related to nature and animals. H. Demonstrate command of the subjunctive mood/tense to express will and emotions. I. Compare the amount of something (a noun).
Culture: A. What are some ecological and environmental concerns and movements in France? B. What are some steps that the French government has taken to combat ecological and environmental problems? C. What do I need to know to be able to talk about France's national parks?	Culture: A. Discuss environmental concerns and ecological movements in France and produce clear and coherent writing samples. B. Investigate and discuss steps taken by the French government to combat environmental and ecological problems. Cite textual evidence. C. Discuss some of the national parks in France and what they have to offer.
Comparisons: A. What are the differences and similarities between environmental and ecological problems in France and environmental and ecological problems in the United States? B. What are some geographical and recreational similarities and differences between national parks in France and the United States? C. What is the attitude of Americans towards the environment and how does this compare to the attitude of the French?	Comparisons: A. Compare and contrast ecological and environmental problems in France and the USA. B. Compare and contrast geographical and recreational similarities and differences between national parks in France and the United States? C. Discuss the similarities and differences in the attitude of the Americans and the attitude of the French towards environmental concerns.
Connections: A. What information do I need to be able to make a positive contribution to the environment? B. What information do I know about national parks in the United States?	Connections: A. Research and investigate ways of protecting the environment. B. Activate prior knowledge of national parks in the United States.

World Languages: French Level 3

TOPIC: ECOLOGY

Communities:

- A. What effects do environmental issues have on my local community?
- B. How are local parks administered or protected?

Communities:

- A. Assess the impact of environmental issues on the community.
- B. Cite evidence to show the impact of environmental issues on the community.
- C. Investigate the leadership and protection of local interests.

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

- Model vocabulary, grammar and idiomatic expressions.
- Incorporate video or audio segments from target cultures.
- Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
- Create and utilize communicative activities.
- Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
- Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
- Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
- Design and utilize PowerPoint/SMART board presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**
- Complete online exercises.
- Scaffold prior vocabulary.
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture.
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities.
- Create Total Physical Response (TPR) activities.

Assessments:

In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Reading with Depth of Knowledge leveled questions based on readings on pages 249 & 256 (RI 1, W4, W10)
- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes (L1, L2,)
- Cloze activities
- Summative performance assessments (oral or in writing)

World Languages: French Level 3

TOPIC: ECOLOGY

- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 2, Unité 6
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: French Level 3

TOPIC: PERFORMANCE ARTS

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
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CONTENT STANDARD 8: Comparisons Among Cultures
CONTENT STANDARD 9: Communities

1.3.1 Exchange information about current and past events, as well as aspirations in their personal lives and the lives of their friends, families and others within their community.

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.4 Work in groups to develop solutions to problems that are of contemporary or historical interest in both the target and their native cultures.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

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5.2.2 Acquire more detailed information from a variety of sources in the world language classroom and integrate it with other school subjects, comparing and evaluating the similarities and differences in information.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

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TOPIC: PERFORMANCE ARTS

5.3.4 Use new information and perspectives gained through world language study to expand their personal knowledge and interdisciplinary connections.

6.3.1 Use multiple media resources to analyze aspects of the target culture(s) and apply their knowledge to new situations.

7.2.4 Expand comprehension strategies to predict outcomes and make comparisons.

7.3.1 Analyze various elements of the target language (such as time or tense), and compare and contrast them with comparable linguistic elements in English.

7.3.2 Evaluate the style of a communicative interaction in the target language.

8.3.2 Compare and contrast the treatment of current issues across cultures by drawing on authentic texts.

8.3.3 Analyze how other cultures view the role of the United States in the world arena.

8.3.4 Use new information and perspectives to compare and contrast their experiences with those of their peers in the target culture(s).

8.3.5 Use new and evolving information and perspectives to demonstrate understanding of the similarities and differences across cultures.

8.3.6 Use new and evolving information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

9.3.1 Communicate with members of the target culture and interpret information regarding topics of personal, community or world interest.

9.3.4 Use various media from the target language and culture for personal enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

1.3.1, 1.3.3, 1.3.4, 1.3.7, 2.2.1, 2.2.3, 2.2.5, 2.2.6, 3.2.1, 4.3.1, 4.3.2, 4.3.4, 4.3.5, 5.2.2, 5.3.1, 5.3.4, 6.3.1, 7.2.4, 7.3.1, 7.3.2, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 8.3.6, 9.2.7, 9.3.1, 9.3.4

Common Core State Standards for English Language Arts

The Common Core Standards are written for instruction in English; students will strengthen and reinforce their understanding of such skills in English by mastering some of the following standards in French:

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

WRITING: W

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI 6 Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

W 4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W 5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 9–10 on page 54.)

W 6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

W 9b Apply *grades 11-12 Reading standards* to literary nonfiction (e.g., "Delineate and evaluate the argument

World Languages: French Level 3

TOPIC: PERFORMANCE ARTS

and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning”).

W 10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

SL 1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grades 11-12 topics, texts, and issues*, building on others’ ideas and expressing their own clearly and persuasively.

SL 1a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well reasoned exchange of ideas.

SL 1b Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

SL 1c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

SL 1d Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL 3 Evaluate a speaker’s point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

L1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

L 2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 2b Spell correctly.

L 3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

L 4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on *grades 11–12 reading and content*, choosing flexibly from a range of strategies.

L 4a Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., *conceive, conception, conceivable*).

L4 c Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

L 4d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understating of figurative language, word relationships, and nuances in word meanings.

L 5b Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

World Languages: French Level 3	
TOPIC: <u>PERFORMANCE ARTS</u>	
UNWRAPPED PERFORMANCE STANDARDS	
<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Exchange	Information (ecology, environment, nature, conservation)
Describe	Activities (preserving and destroying the environment)
Discuss	Environment and surroundings
Compare and contrast	People, places and things (nouns)
Use	Subjective and impersonal expressions
Identify	National parks
Comprehend	Conversations (environmental)
Comprehend	Main ideas (listening)
Develop	Logical arguments
Create	Writing samples
Apply	Concepts (subjunctive rules and usage)
Use	Multimedia sources
Exhibit	Awareness of audience (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of behavior (environmental attitude)
Analyze	Authentic cultural experiences
Evaluate	Cultural practices
Formulate	Conclusions (culture)

World Languages: French Level 3

TOPIC: PERFORMANCE ARTS

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>PERFORMANCE ARTS</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. What do I need to know to be able to talk theater and performance arts? B. How do I express doubt, disbelief and uncertainty? C. How do I express possession? D. How do I talk about films and television programs? E. What do I need to know to be able to talk about different kinds of reading material? F. How do I differentiate between the use	Communication: A. Discuss theater and performance arts. B. Communicate doubt, disbelief and uncertainty. C. C. Use possessive pronouns to replace nouns modified by possessive adjectives. D. Identify and discuss film and television programming vocabulary. E. Discuss books and other reading material.
Culture: A. What are some ecological and environmental concerns and movements in France? B. What are some steps that the French government has taken to combat ecological and environmental problems? C. What do I need to know to be able to talk about France's national parks?	Culture: A. Discuss environmental concerns and ecological movements in France and produce clear and coherent writing samples. B. Investigate and discuss steps taken by the French government to combat environmental and ecological problems. Cite textual evidence. C. Discuss some of the national parks in France and what they have to offer.
Comparisons: A. What are the differences and similarities between environmental and ecological problems in France and environmental and ecological problems in the United States? B. What are some geographical and recreational similarities and differences between national parks in France and the United States? C. What is the attitude of Americans towards the environment and how does this compare to the attitude of the French?	Comparisons: A. Compare and contrast ecological and environmental problems in France and the USA. B. Compare and contrast geographical and recreational similarities and differences between national parks in France and the United States? C. Discuss the similarities and differences in the attitude of the Americans and the attitude of the French towards environmental concerns.
Connections: A. What information do I need to be able to make a positive contribution to the environment? B. What information do I know about national parks in the United States?	Connections: A. Research and investigate ways of protecting the environment. B. Activate prior knowledge of national parks in the United States.
Communities: A. What effects do environmental issues have on my local community? B. How are local parks administered or protected?	Communities: A. Assess the impact of environmental issues on the community. B. Cite evidence to show the impact of environmental issues on the community.

World Languages: French Level 3

TOPIC: PERFORMANCE ARTS

C. Investigate the leadership and protection of local interests.

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

- Model vocabulary, grammar and idiomatic expressions.
- Incorporate video or audio segments from target cultures.
- Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
- Create and utilize communicative activities.
- Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
- Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
- Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
- Design and utilize PowerPoint/SMART board presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**
- Complete online exercises.
- Scaffold prior vocabulary.
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture.
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities.
- Create Total Physical Response (TPR) activities.

Assessments:

In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Reading with Depth of Knowledge leveled questions based on readings on pages 249 & 256 (RI 1, W4, W10)
- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes (L1, L2,)
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)

World Languages: French Level 3

TOPIC: PERFORMANCE ARTS

- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 2, Unité 6
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: French Level 3
TOPIC: PERSONAL RELATIONSHIPS

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
CONTENT STANDARD 2: Communication (Interpretive Mode)
CONTENT STANDARD 3: Communication (Presentational Mode)
CONTENT STANDARD 4: Culture
CONTENT STANDARD 5: Connections (Interdisciplinary Mode)
CONTENT STANDARD 6: Connections (Interdisciplinary Mode)
CONTENT STANDARD 7: Comparisons Among Languages
CONTENT STANDARD 8: Comparisons Among Cultures
CONTENT STANDARD 9: Communities

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.6 Share their personal reactions and feelings about authentic literary texts such as poems, plays, short stories and novels.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

1.3.8 Employ rephrasing and circumlocution, i.e., using other words and gestures to explain words or concepts, to successfully communicate their messages.

2.3.2 Understand the main idea or plot and relevant details or subplots of radio or television programs, films or other forms of media designed primarily by native speakers of the target language.

2.3.4 Recognize the characters and the significance of their roles when reading authentic literary texts and comprehend the main plot and relevant subplot(s).

3.3.2 Perform scenes from plays and/or recite poems or excerpts from short stories in the target language.

3.3.3 Prepare oral and/or written analyses in the target language of the plot, character, descriptions and development, and themes found in authentic literary works, including poems, plays, short stories and short works of fiction or nonfiction.

3.3.4 Describe, explain, express opinions about and analyze stories, plays, poems or other literature, as well as radio programs, music, films, art and websites.

3.3.5 Write letters in the target language to peers in the target culture, describing and analyzing current events of mutual interest

4.3.1 Identify and analyze products and practices of the target culture (e.g., social, economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

4.3.2 Identify, experience or read about, and discuss expressive forms of the culture, including but not limited to literature, periodicals, films, television, websites and the fine arts, in order to explore their effects on the larger community.

4.3.3 Interact in a variety of cultural contexts that reflect both peer group and adult activities within the target culture, using the appropriate verbal and nonverbal clues.

4.3.4 Identify, discuss and analyze various patterns of behaviors or interactions that are typical of the target culture.

4.3.5 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the target culture.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

World Languages: French Level 3
TOPIC: PERSONAL RELATIONSHIPS

5.3.4 Use new information and perspectives gained through world language study to expand their personal knowledge and interdisciplinary connections.
6.3.2 Access and analyze materials, looking for sources of information for potential use in original work on the target language or culture(s).
7.3.2 Evaluate the style of a communicative interaction in the target language.
8.3.1 Discuss and analyze different forms of communication across cultures such as signs, symbols, advertisements, displays, songs and rhymes.
8.3.6 Use new and evolving information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.
9.3.4 Use various media from the target language and culture for personal enjoyment.
9.3.5 Read literature, listen to music and view films and websites in the target language for entertainment.

Connecticut Frameworks Performance Standards (CSDE)

1.3.3, 1.3.6, 1.3.7, 1.3.8, 2.3.2, 2.3.4, 3.3.2, 3.3.3, 3.3.4, 3.3.5, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 5.3.1, 5.3.4, 6.3.2, 7.3.2, 8.3.1, 8.3.6, 9.3.4, 9.3.5

Common Core State Standards for English Language Arts

The Common Core Standards are written for instruction in English; students will strengthen and reinforce their understanding of such skills in English by mastering some of the following standards in French.

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

Writing: W

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RL 4 Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the impact of specific word choices on meaning and tone, including words with multiple meanings or language that is particularly fresh, engaging, or beautiful. (Include Shakespeare as well as other authors.)
RL 6 Analyze a case in which grasping point of view requires distinguishing what is directly stated in a text from what is really meant (e.g., satire, sarcasm, irony, or understatement).
RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.
W 2 Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.
W 2 a Introduce a topic; organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
W 2 b Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
W 2 c Use appropriate and varied transitions and syntax to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.
W 2 d Use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic.
W 2 e Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
W 2 f Provide a concluding statement or section that follows from and supports the information or explanation

World Languages: French Level 3
TOPIC: PERSONAL RELATIONSHIPS

presented (e.g., articulating implications or the significance of the topic).

W 4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W 5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 11–12 on page 54.)

W 6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

W 7 Conduct short as well as more sustained research projects to answer a question

(including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

W 8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

W 9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

W 9 a Apply *grades 11–12 Reading standards* to literature (e.g., “Demonstrate knowledge of eighteenth-, nineteenth- and early-twentieth-century foundational works of American literature, including how two or more texts from the same period treat similar themes or topics”).

W 10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

SL 1 Initiate and participate effectively in a range of collaborative discussions one on-one, in groups, and teacher-led) with diverse partners on *grades 11–12 topics ,texts, and issues*, building on others’ ideas and expressing their own clearly and persuasively.

SL 1 a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well reasoned exchange of ideas.

SL 1 . Work with peers to promote civil, democratic discussions and decision making, set clear goals and deadlines, and establish individual roles as needed.

SL 1 c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

SL 1 d Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL 4 Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

L 1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

L 1 b Resolve issues of complex or contested usage, consulting references (e.g., *Merriam-Webster’s Dictionary of English Usage*, *Garner’s Modern American Usage*) as needed.

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

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TOPIC: PERSONAL RELATIONSHIPS

- b. Spell correctly.
- L 3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
- L 4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on *grades 11–12 reading and content*, choosing flexibly from a range of strategies.
- L 4 a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.
- L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., *conceive, conception, conceivable*).
- L 4 c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.
- L 4 d. Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).
- L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.
- L 5 a. Interpret figures of speech (e.g., hyperbole, paradox) in context and analyze their role in the text.
- L 5 b. Analyze nuances in the meaning of words with similar denotations.
- L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Discuss	Feelings, relationships, personalities
Compare and contrast	Verb forms
Describe	Author’s craft
Identify	Spell-changing verbs, irregular verbs
Comprehend	Conversations
Comprehend	Main ideas (reading, listening)
Develop	Logical arguments
Create	Writing samples
Apply	Concepts (grammar, literary)
Use	Multimedia sources
Exhibit	Awareness (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of behavior
Analyze	Authentic cultural experiences
Evaluate	Francophone Cuisine and Music (culture)
Formulate	Conclusions (culture)
Create	Authentic Francophone Cuisine

World Languages: French Level 3
TOPIC: PERSONAL RELATIONSHIPS

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>PERSONAL RELATIONSHIPS</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I interpret vocabulary related to relationships, feelings, marriage, and personality? B. How do I express my love interests to another? C. How do I read and analyze poetry in the target language and in English? D. How do I use –ger, -cer, -yer, and other spell changing verbs? E. How do use common irregular verbs in everyday conversation? F. How do I form questions?	Communication: A. Discuss relationships, feelings, marriage, and personalities. B. Read and watch the short film <i>à tes amours</i> . C. Read and analyze <i>Il pleut dans mon cœur</i> by Paul Verlaine and read and analyze a popular/favorite poem in English. D. Use –ger, -cer, -yer and other spell changing verbs to discuss daily activities. E. Use common irregular verbs to talk about everyday occurrences and activities. F. Construct questions.
Culture: A. What do I need to know to be able to talk about the American chef, Julia Child? B. What are some idiomatic expressions used in the target culture to describe feelings and relationships?	Culture: A. Read a short excerpt about the American chef, Julia Child. B. Use idiomatic expressions to talk about feelings and relationships.
Comparisons: A. What connections are there between the United States and France? B. What are the similarities and differences between French education in schools in Louisiana and French education in schools in the United States?	Comparisons: A. Discuss and compare the connections between the United States and France. B. Cite evidence of French education in Louisiana versus other states.
Connections: A. What information do I need to be able to create an authentic French cuisine? B. What prior knowledge do I have of poetry? C. What prior knowledge do I have of Louisiana?	Connections: A. Create an authentic Francophone dish. B. Activate prior knowledge of poetry. C. Activate prior knowledge of Louisiana.
Communities: A. How is Francophone cuisine represented in our local community? B. How is Francophone music represented in our local community?	Communities: A. Research local restaurants and cafés that serve Francophone cuisine. B. Research local venues that might play Francophone music.

World Languages: French Level 3
TOPIC: PERSONAL RELATIONSHIPS

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

- Model vocabulary, grammar and idiomatic expressions.
- Incorporate video or audio segments from target cultures.
- Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
- Create and utilize communicative activities.
- Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
- Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
- Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
- Design and utilize PowerPoint/SMART board presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**
- Complete online exercises.
- Scaffold prior vocabulary.
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture.
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities.
- Create Total Physical Response (TPR) activities.

Assessments:

In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- **Assessments will be modified through the use of word banks and models for Academic classes**

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TOPIC: <u>PERSONAL RELATIONSHIPS</u>

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 3, Leçon 1
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

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TOPIC: LIVING IN THE CITY

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
CONTENT STANDARD 2: Communication (Interpretive Mode)
CONTENT STANDARD 3: Communication (Presentational Mode)
CONTENT STANDARD 4: Culture
CONTENT STANDARD 5: Connections (Interdisciplinary Mode)
CONTENT STANDARD 6: Connections (Interdisciplinary Mode)
CONTENT STANDARD 7: Comparisons Among Languages
CONTENT STANDARD 8: Comparisons Among Cultures
CONTENT STANDARD 9: Communities

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.6 Share their personal reactions and feelings about authentic literary texts such as poems, plays, short stories and novels.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

1.3.8 Employ rephrasing and circumlocution, i.e., using other words and gestures to explain words or concepts, to successfully communicate their messages.

2.3.2 Understand the main idea or plot and relevant details or subplots of radio or television programs, films or other forms of media designed primarily by native speakers of the target language.

2.3.4 Recognize the characters and the significance of their roles when reading authentic literary texts and comprehend the main plot and relevant subplot(s).

3.3.2 Perform scenes from plays and/or recite poems or excerpts from short stories in the target language.

3.3.3 Prepare oral and/or written analyses in the target language of the plot, character, descriptions and development, and themes found in authentic literary works, including poems, plays, short stories and short works of fiction or nonfiction.

3.3.4 Describe, explain, express opinions about and analyze stories, plays, poems or other literature, as well as radio programs, music, films, art and websites.

3.3.5 Write letters in the target language to peers in the target culture, describing and analyzing current events of mutual interest

4.3.1 Identify and analyze products and practices of the target culture (e.g., social, economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

4.3.2 Identify, experience or read about, and discuss expressive forms of the culture, including but not limited to literature, periodicals, films, television, websites and the fine arts, in order to explore their effects on the larger community.

4.3.3 Interact in a variety of cultural contexts that reflect both peer group and adult activities within the target culture, using the appropriate verbal and nonverbal clues.

4.3.4 Identify, discuss and analyze various patterns of behaviors or interactions that are typical of the target culture.

4.3.5 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the target culture.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

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TOPIC: LIVING IN THE CITY

5.3.4 Use new information and perspectives gained through world language study to expand their personal knowledge and interdisciplinary connections.
6.3.2 Access and analyze materials, looking for sources of information for potential use in original work on the target language or culture(s).
7.3.2 Evaluate the style of a communicative interaction in the target language.
8.3.1 Discuss and analyze different forms of communication across cultures such as signs, symbols, advertisements, displays, songs and rhymes.
8.3.6 Use new and evolving information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.
9.3.4 Use various media from the target language and culture for personal enjoyment.
9.3.5 Read literature, listen to music and view films and websites in the target language for entertainment.

Connecticut Frameworks Performance Standards (CSDE)

1.3.3, 1.3.6, 1.3.7, 1.3.8, 2.3.2, 2.3.4, 3.3.2, 3.3.3, 3.3.4, 3.3.5, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 5.3.1, 5.3.4, 6.3.2, 7.3.2, 8.3.1, 8.3.6, 9.3.4, 9.3.5

Common Core State Standards for English Language Arts

In mastering the following standards in French, students are expected to reinforce their understanding of such skills in English.

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RL 4 Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the cumulative impact of specific word choices on meaning and tone (e.g., how the language evokes a sense of time and place; how it sets a formal or informal tone).

RL 6 Analyze a particular point of view or cultural experience reflected in a work of literature from outside the United States, drawing on a wide reading of world literature.

RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

SL 1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grades 9–10 topics, texts, and issues*, building on others' ideas and expressing their own clearly and persuasively.

SL 1a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

SL 1 b Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.

SL 1 c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

SL 1 d Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.

SL 4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

World Languages: French Level 3

TOPIC: LIVING IN THE CITY

- L 1** Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
- L 1 b** Use various types of phrases (noun, verb, adjectival, adverbial, participial, prepositional, absolute) and clauses (independent, dependent; noun, relative, adverbial) to convey specific meanings and add variety and interest to writing or presentations.
- L 2** Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
- L 2 c** Spell correctly.
- L 3** Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
- L 4** Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.
- L 4 a** Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.
- L 4 b** Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).
- L 4 c** Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.
- L 4 d** Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).
- L 5** Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.
- L 5 a** Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.
- L 5 b.** Analyze nuances in the meaning of words with similar denotations.
- L 6** Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Discuss	Feelings, relationships, personalities
Compare and contrast	Verb forms
Describe	Author's craft
Identify	Spell-changing verbs, irregular verbs
Comprehend	Conversations
Comprehend	Main ideas (reading, listening)
Develop	Logical arguments
Create	Writing samples
Apply	Concepts (grammar, literary)
Use	Multimedia sources
Exhibit	Awareness (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of behavior

World Languages: French Level 3	
TOPIC: <u>LIVING IN THE CITY</u>	
Analyze	Authentic cultural experiences
Evaluate	Francophone Cuisine and Music (culture)
Formulate	Conclusions (culture)
Create	Authentic Francophone Cuisine

World Languages: French Level 3

TOPIC: LIVING IN THE CITY

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>LIVING IN THE CITY</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I interpret vocabulary related to relationships, feelings, marriage, and personality? B. How do I express my love interests to another? C. How do I read and analyze poetry in the target language and in English? D. How do I use –ger, -cer, -yer, and other spell changing verbs? E. How do use common irregular verbs in everyday conversation? F. How do I form questions?	Communication: A. Discuss relationships, feelings, marriage, and personalities. B. Read and watch the short film <i>à tes amours</i> . C. Read and analyze <i>Il pleut dans mon cœur</i> by Paul Verlaine and read and analyze a popular/favorite poem in English. D. Use –ger, -cer, -yer and other spell changing verbs to discuss daily activities. E. Use common irregular verbs to talk about everyday occurrences and activities. F. Construct questions.
Culture: A. What do I need to know to be able to talk about the American chef, Julia Child? B. What are some idiomatic expressions used in the target culture to describe feelings and relationships?	Culture: A. Read a short excerpt about the American chef, Julia Child. B. Use idiomatic expressions to talk about feelings and relationships.
Comparisons: A. What connections are there between the United States and France? B. What are the similarities and differences between French education in schools in Louisiana and French education in schools in the United States?	Comparisons: A. Discuss and compare the connections between the United States and France. B. Cite evidence of French education in Louisiana versus other states.
Connections: A. What information do I need to be able to create an authentic French cuisine? B. What prior knowledge do I have of poetry? C. What prior knowledge do I have of Louisiana?	Connections: A. Create an authentic Francophone dish. B. Activate prior knowledge of poetry. C. Activate prior knowledge of Louisiana.
Communities: A. How is Francophone cuisine represented in our local community? B. How is Francophone music represented in our local community?	Communities: A. Research local restaurants and cafés that serve Francophone cuisine. B. Research local venues that might play Francophone music.

World Languages: French Level 3

TOPIC: LIVING IN THE CITY

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

- Model vocabulary, grammar and idiomatic expressions.
- Incorporate video or audio segments from target cultures.
- Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
- Create and utilize communicative activities.
- Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
- Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
- Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
- Design and utilize PowerPoint/SMART board presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**
- Complete online exercises.
- Scaffold prior vocabulary.
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture.
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities.
- Create Total Physical Response (TPR) activities.

Assessments:

In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- **Assessments will be modified through the use of word banks and models for Academic classes**

World Languages: French Level 3

TOPIC: LIVING IN THE CITY

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 3, Leçon 1
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: French Level 3

TOPIC: THE MEDIA

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
CONTENT STANDARD 2: Communication (Interpretive Mode)
CONTENT STANDARD 3: Communication (Presentational Mode)
CONTENT STANDARD 4: Culture
CONTENT STANDARD 5: Connections (Interdisciplinary Mode)
CONTENT STANDARD 6: Connections (Interdisciplinary Mode)
CONTENT STANDARD 7: Comparisons Among Languages
CONTENT STANDARD 8: Comparisons Among Cultures
CONTENT STANDARD 9: Communities

1.3.1 Exchange information about current and past events, as well as aspirations in their personal lives and the lives of their friends, families and others within their community.

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.4 Work in groups to develop solutions to problems that are of contemporary or historical interest in both the target and their native cultures.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest.

2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources.

2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles.

2.2.6 Begin to make informed hypotheses about the meaning of unfamiliar, more complicated passages in the target language, based on contextual clues.

3.2.1 Make brief presentations to their class in the target language on topics of personal interest or topics that have been studied in other subject areas.

4.3.1 Identify and analyze products and practices of the target culture (e.g., social, economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

4.3.2 Identify, experience or read about, and discuss expressive forms of the culture, including but not limited to literature, periodicals, films, television, websites and the fine arts, in order to explore their effects on the larger community.

4.3.4 Identify, discuss and analyze various patterns of behaviors or interactions that are typical of the target culture.

4.3.5 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the target culture.

5.2.2 Acquire more detailed information from a variety of sources in the world language classroom and integrate it with other school subjects, comparing and evaluating the similarities and differences in information.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

5.3.4 Use new information and perspectives gained through world language study to expand their personal

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TOPIC: THE MEDIA

knowledge and interdisciplinary connections.

6.3.1 Use multiple media resources to analyze aspects of the target culture(s) and apply their knowledge to new situations.

7.2.4 Expand comprehension strategies to predict outcomes and make comparisons.

7.3.1 Analyze various elements of the target language (such as time or tense), and compare and contrast them with comparable linguistic elements in English.

7.3.2 Evaluate the style of a communicative interaction in the target language.

8.3.2 Compare and contrast the treatment of current issues across cultures by drawing on authentic texts.

8.3.3 Analyze how other cultures view the role of the United States in the world arena.

8.3.4 Use new information and perspectives to compare and contrast their experiences with those of their peers in the target culture(s).

8.3.5 Use new and evolving information and perspectives to demonstrate understanding of the similarities and differences across cultures.

8.3.6 Use new and evolving information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

9.3.1 Communicate with members of the target culture and interpret information regarding topics of personal, community or world interest.

9.3.4 Use various media from the target language and culture for personal enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

1.3.1, 1.3.3, 1.3.4, 1.3.7, 2.2.1, 2.2.3, 2.2.5, 2.2.6, 3.2.1, 4.3.1, 4.3.2, 4.3.4, 4.3.5, 5.2.2, 5.3.1, 5.3.4, 6.3.1, 7.2.4, 7.3.1, 7.3.2, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 8.3.6, 9.2.7, 9.3.1, 9.3.4

Common Core State Standards for English Language Arts

The Common Core Standards are written for instruction in English; students will strengthen and reinforce their understanding of such skills in English by mastering some of the following standards in French:

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

WRITING: W

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI 6 Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

W 4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W 5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 9–10 on page 54.)

W 6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

W 9b Apply *grades 11–12 Reading standards* to literary nonfiction (e.g., "Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and

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TOPIC: THE MEDIA

sufficient; identify false statements and fallacious reasoning”).

W 10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

SL 1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grades 11-12 topics, texts, and issues*, building on others’ ideas and expressing their own clearly and persuasively.

SL 1a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well reasoned exchange of ideas.

SL 1b Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

SL 1c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

SL 1d Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL 3 Evaluate a speaker’s point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

L1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

L 2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 2b Spell correctly.

L 3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

L 4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on *grades 11–12 reading and content*, choosing flexibly from a range of strategies.

L 4a Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., *conceive*, *conception*, *conceivable*).

L4 c Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

L 4d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understating of figurative language, word relationships, and nuances in word meanings.

L 5b Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

World Languages: French Level 3	
TOPIC: <u>THE MEDIA</u>	
UNWRAPPED PERFORMANCE STANDARDS	
<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Exchange	Information (media, people of the media, film, television, press)
Discuss	Quebec, a francophone province of Canada
Compare and contrast	Tenses
Use	The past tense
Distinguish between	The passé composé and the imperfect
Comprehend	Main ideas (listening)
Develop	Logical arguments
Create	Writing samples using 2 tenses
Apply	Concepts (subjunctive rules and usage)
Use	Multimedia sources
Exhibit	Awareness of audience (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of behavior (environmental attitude)
Analyze	Authentic cultural experiences
Evaluate	Cultural practices
Formulate	Conclusions (culture)

World Languages: French Level 3

TOPIC: THE MEDIA

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>THE MEDIA</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. What do I need to know to be able to talk the media? B. How do I talk about things that used to take place regularly in the past? C. What do I need to know to be able to discuss completed actions in the past? D. What tools do I need to be able to listen and respond to short films in the target language?	Communication: A. Identify and demonstrate command of vocabulary related the different aspects of the media. B. Discuss and write using the imperfect tense. C. Discuss and write using the passé composé . D. Discuss and apply comprehension techniques to the short film, Emilie Muller .
Culture: A. What information do I need to know to discuss Quebec's fight for independence? B. What are some commonly used phrases in Quebec? C. What are some of the well-known activities and sights in Quebec?	Culture: A. Read about Quebec and discuss different points of view regarding sovereignty. B. Discuss and appropriately use some commonly used expressions in Quebec. C. Research and share some of the well-known sights in Quebec and what people typically do.
Comparisons: A. What are the differences and similarities between the media influence in the United States and the media Influence in the francophone world? B. How do newspapers and print media in francophone countries differ from print media in the United States? How are they similar? C. How does the French language spoken to Quebec differ from France's French?	Comparisons: A. Read about and discuss the influence of the media on people (especially the peer-group) in both the US and the francophone world. B. Compare and contrast print media from the US and francophone countries. C. Compare France's French to Quebec's French.
Connections: A. How do the media use its influence to sway people's thoughts?	Connections: A. Discuss the music of Félix Leclerc and Gilles Vigneault and its impact on the idea of sovereignty in Quebec.
Communities: A. How do the media affect and influence my local community?	Communities: A. Discuss the effect of the media on the local community and local activities.

World Languages: French Level 3

TOPIC: THE MEDIA

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

- Model vocabulary, grammar and idiomatic expressions.
- Incorporate video or audio segments from target cultures.
- Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
- Create and utilize communicative activities.
- Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
- Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
- Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
- Design and utilize PowerPoint/SMART board presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**
- Complete online exercises.
- Scaffold prior vocabulary.
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture.
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities.
- Create Total Physical Response (TPR) activities.

Assessments:

In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Reading with Depth of Knowledge leveled questions based on readings on pages 249 & 256 (RI 1, W4, W10)
- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes (L1, L2,)
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- **Assessments will be modified through the use of word banks and models for Academic classes**

World Languages: French Level 3

TOPIC: THE MEDIA

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 2, Unité 6
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: French Level 3

TOPIC: IT'S THE LAW

Connecticut Frameworks Content Standards (CSDE)

CONTENT STANDARD 1: Communication (Interpersonal Mode)
CONTENT STANDARD 2: Communication (Interpretive Mode)
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CONTENT STANDARD 6: Connections (Interdisciplinary Mode)
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CONTENT STANDARD 9: Communities

1.3.1 Exchange information about current and past events, as well as aspirations in their personal lives and the lives of their friends, families and others within their community.

1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences.

1.3.4 Work in groups to develop solutions to problems that are of contemporary or historical interest in both the target and their native cultures.

1.3.7 Discuss their personal feelings and ideas with members of the target culture in order to consider alternate viewpoints.

2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest.

2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources.

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4.3.1 Identify and analyze products and practices of the target culture (e.g., social, economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

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4.3.4 Identify, discuss and analyze various patterns of behaviors or interactions that are typical of the target culture.

4.3.5 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the target culture.

5.2.2 Acquire more detailed information from a variety of sources in the world language classroom and integrate it with other school subjects, comparing and evaluating the similarities and differences in information.

5.3.1 Use information acquired from other school subjects to complete activities in the world language classroom.

5.3.4 Use new information and perspectives gained through world language study to expand their personal

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TOPIC: IT'S THE LAW

knowledge and interdisciplinary connections.

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7.3.1 Analyze various elements of the target language (such as time or tense), and compare and contrast them with comparable linguistic elements in English.

7.3.2 Evaluate the style of a communicative interaction in the target language.

8.3.2 Compare and contrast the treatment of current issues across cultures by drawing on authentic texts.

8.3.3 Analyze how other cultures view the role of the United States in the world arena.

8.3.4 Use new information and perspectives to compare and contrast their experiences with those of their peers in the target culture(s).

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9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

9.3.1 Communicate with members of the target culture and interpret information regarding topics of personal, community or world interest.

9.3.4 Use various media from the target language and culture for personal enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

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Common Core State Standards for English Language Arts

The Common Core Standards are written for instruction in English; students will strengthen and reinforce their understanding of such skills in English by mastering some of the following standards in French:

READING STANDARDS FOR LITERATURE: RL

READING STANDARDS FOR INFORMATIONAL TEXT: RI

WRITING: W

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

RI 1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI 6 Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

W 4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W 5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 9–10 on page 54.)

W 6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

W 9b Apply *grades 11–12 Reading standards* to literary nonfiction (e.g., "Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and

World Languages: French Level 3

TOPIC: IT'S THE LAW

sufficient; identify false statements and fallacious reasoning”).

W 10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

SL 1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grades 11-12 topics, texts, and issues*, building on others’ ideas and expressing their own clearly and persuasively.

SL 1a Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well reasoned exchange of ideas.

SL 1b Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

SL 1c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

SL 1d Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL 3 Evaluate a speaker’s point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

L1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

L 2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 2b Spell correctly.

L 3 Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

L 4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on *grades 11–12 reading and content*, choosing flexibly from a range of strategies.

L 4a Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., *conceive, conception, conceivable*).

L4 c Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

L 4d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understating of figurative language, word relationships, and nuances in word meanings.

L 5b Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

World Languages: French Level 3	
TOPIC: <u>IT'S THE LAW</u>	
UNWRAPPED PERFORMANCE STANDARDS	
<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
Exchange	Information (the law, legal rights, politics, public officials and national security)
Discuss	The Antilles
Compare and contrast	Life in the Antilles with life in Mainland France
Use	The plus-que parfait
Discuss	Piracy in the Antilles
Comprehend	Main ideas (listening)
Develop	Logical arguments
Create	Writing samples using irregular ir verbs
Use	Multimedia sources
Exhibit	Awareness of audience (phonetics, writing)
Demonstrate, compare & contrast	Knowledge of Haiti's culture and history
Analyze	Authentic cultural experiences
Evaluate	Cultural practices
Formulate	Conclusions (culture)

World Languages: French Level 3

TOPIC: IT'S THE LAW

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. The ability to acknowledge and understand of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

World Languages: French Level 3	
TOPIC: <u>IT'S THE LAW</u>	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. What do I need to know to be able to talk about the law, people's rights and politics? B. How do I talk about public figures? C. What do I need to be able to speak in the negative in both the present and the past tense? D. What are some irregular ir verbs and how do I use them in everyday conversation? E. How do I talk about security and danger? F. How do I talk about something that someone had done? G. How do I use indefinite adjectives and pronouns?	Communication: A. Discuss terms related to the law, legal rights and politics. B. Discuss vocabulary related to people in the public eye. C. Use the different forms of expressing the negative in both present and past tense sentences. D. Apply the appropriate conjugations of irregular ir verbs. E. Discuss and apply vocabulary related to security issues and dangerous situations. F. Use the plus-que-parfait to talk about a past tense context that has already been established and to discuss something that happened even before that. G. Use indefinite adjectives and pronouns to qualify nouns and subjects.
Culture: A. What are some typical cultural practices in the Antilles? B. What do I need to know to be able to communicate effectively in the francophone Antilles? C. How does piracy affect daily living in the Antilles? D. Where outside of the classroom can I use French?	Culture: A. Discuss Guadeloupean folk music and dance. B. Discuss words and expressions that are commonly used in the francophone Antilles. C. Read about and discuss piracy in the Antilles. D. Discuss current and former islands in the French West Indies.
Comparisons: A. How does life differ in France from life in the French-speaking Antilles?	Comparisons: A. Compare and contrast living in France with living in the Antilles.
Connections: A. What tools do I need to have to be able to accurately locate the islands in the Antilles? B. What influence did France have on the current status of the Antilles? C. How do I explain the connection between France and Guadeloupe/Martinique? D. What do I need to know to talk about the structure of the island of Hispaniola?	Connections: A. Apply knowledge of the colonization by the French to be able to identify the islands located in the Caribbean. B. Discuss France's colonization on the current cultural and economic status of the Antilles. C. Examine the connection that Guadeloupe/Martinique has with Mainland France. D. Discuss Haiti's connection to Hispaniola and the discovery by Christopher Columbus and the ultimate split of the island.

World Languages: French Level 3	
TOPIC: <u>IT'S THE LAW</u>	
Communities: A. What are some dangers/legal problems affecting my local community? B. Who are some people in the public eye from my community?	Communities: A. Discuss the local community and legal problems that it faces. B. Discuss people in the public eye.
INSTRUCTIONAL STRATEGIES: Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:	
• Model vocabulary, grammar and idiomatic expressions. • Incorporate video or audio segments from target cultures. • Facilitate classroom discussions that examine and compare cultural differences. Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class. • Create and utilize communicative activities. • Support peer teaching. Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching. • Design various practice activities for vocabulary acquisition and retention. Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities. • Use readings from textbook. Accl: Students are given more target language readings especially in the culture segments of the unit. • Design and utilize PowerPoint/SMART board presentations Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance. • Complete online exercises. • Scaffold prior vocabulary. • Utilize peer editing to further enhance writing skills. • Require students to access program Internet activities including but not limited to current news clips • Invite classroom speakers from target culture. • Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning • Require students to participate in teacher-created web-based activities. • Create Total Physical Response (TPR) activities.	
Assessments: In order to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:	
• Reading with Depth of Knowledge leveled questions based on readings on pages 249 & 256 (RI 1, W4, W10) • Writing prompts in the target language Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language • Dialogues and role-play activities in the target language Accl: Memorization of dialogues • Reading and listening comprehension activities • Vocabulary and structure quizzes (L1, L2,) • Cloze activities • Summative performance assessments (oral or in writing)	

World Languages: French Level 3

TOPIC: IT'S THE LAW

- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *D'accord!* 2, Unité 6
- Student materials (Student book, workbooks)
- ***Accl: Maestro SuperSite (cahier interactif, audio, video & practice)***
- Teacher materials: DVDs (Roman-photo, flash culture, Maestro SuperSite)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

Bristol Public Schools

Office of Teaching & Learning

DEPARTMENT: World Languages

COURSE: Spanish IV

COURSE DESCRIPTION: Spanish IV continues the development of the essential communicative skills acquired over the last three years. The comprehension and speaking skills are expanded, but with more attention being given to complex reading and writing structures. The study of geography, history and culture of the Spanish speaking world is continued.

PREREQUISITES: Spanish III

DEPARTMENT PHILOSOPHY: Our primary goal is to help all students develop linguistic proficiency and cultural sensitivity in a second language of their choice. We believe that all students can benefit from second language instruction. We recognize that not everyone learns at the same rate or in the same way; nevertheless, we believe that all students should have the opportunity to acquire language proficiency to a degree commensurate with their individual abilities. In the 21st century, the need for effective communication and sensitivity to other cultures has become even more important. We believe that the study of more than one language is essential to meeting these global needs.

DEPARTMENT GOALS: Through a planned, sequential curriculum, Bristol Public schools strives to educate each student in conjunction with the State Standards for World Languages education. Students should be able to demonstrate skills and knowledge in each of the following standards:

- .. Communicate in at least one language other than English;
- .. Gain knowledge and understanding of other cultures;
- .. Make connections with other areas of study and acquire information;
- .. Understand the nature of language and cultures through comparisons; and
- .. Participate in multilingual communities within a variety of contexts.

Academic and Accelerated Objectives: Standards are taught in academic and accelerated classes. The coursework is differentiated in lesson objectives, assessments, pacing and performance, with an expectation that accelerated students speak and read with greater independence and fluency. Accelerated students are expected to meet all objectives for the course as well as those that go beyond the academic level and are printed in **bold** and ***italicized***. **Differentiation strategies**, assessments and activities for accelerated students are also written in **bold** and ***italicized***. Essential questions and learning objectives align by categorization (i.e. **culture** related essential questions are aligned with **culture**-related learning objectives)

World Languages: Spanish IV
Unit 1 <u>¡Encantada de conocerlo!</u>
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
1.2.1 Exchange information with peers and the teacher (both face-to-face and in writing) about events in their everyday lives and experiences from their past. 1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences. 2.1.7 Comprehend the principal message of highly illustrated texts in which cognates are used, including stories, newspaper articles and advertisements. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families and their school activities. 4.1.4 Participate in age-appropriate cultural activities, such as games, songs, birthday celebrations, storytelling, dramatizations or role-playing of the target culture. 4.2.5 Observe, identify and discuss patterns of behavior or interaction that are typical of their peer group in the target culture. 5.2.3 Use new information and critical thinking gained through world language study to expand their personal knowledge. 7.2.1 Understand how idiomatic expressions affect communications and reflect culture. 8.1.5 Use new information and cultural awareness to compare and contrast their experiences with those of their peers in the target culture(s) and to identify with and respect peers in the target culture(s). 9.2.1 Discuss their families, school experiences, free-time activities and current events in the target language in oral or written form.
Connecticut Frameworks Performance Standards (CSDE) 1.2.1, 1.3.3, 2.1.7, 3.1.3, 4.1.4, 4.2.5, 5.2.3, 7.2.1, 8.1.5, 9.2.1
Common Core State Standards for English Language Arts In mastering the following standards in Spanish, students are expected to reinforce their understanding of such skills in English SPEAKING AND LISTENING STANDARD: SL LANGUAGE STANDARD: L SL 9.1.c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion;

and clarify, verify, or challenge ideas and conclusions.

L 9.2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 9.2.c. Spell correctly.

L 4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.

L 4.a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

L 4.c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.

L 4 d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L 5 a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L 5 b. Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

UNWRAPPED PERFORMANCE STANDARDS

<i>Skills</i> <i>What students need to be able to do – verbs</i>	<i>Concepts</i> <i>What students need to know about - nouns</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (personal)
3. Share	Personal reactions and feelings
CS2	
1. Understand	Main ideas, themes, details (descriptions, exclamations, questions)
2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)
CS3	

1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I greet people? B. How do I ask questions and express emotions? C. What information do I need to analyze the importance of friendship? D. How do I describe people and things? E. How do I point someone or something out? F. How do I divide words into syllables? G. How do I obtain information to write an article about a friend?	Communication: A. Greet friends and say farewells. B. Ask for information and help. C. Express excitement and disappointment. D. Describe people and things. E. introduce friends. F. Use office and courtesy expressions. G. Write an article about a friend.
Culture: A. What are the different places that one can visit in Cuba? B. What famous people originated from Cuba?	Culture: A. Recognize places to visit in Cuba. B. Identify Ibrahim Ferrer. C. Understand cultural perspectives of Cuba.
Comparisons: A. What are the differences and similarities between friendships in U.S and Cuba?	Comparisons: A. Compare and contrast types of personalities. B. Write their own definition of <i>amistad</i>

	(friendship).
Connections: A. What information do I need to analyze the importance of friendship? B. How do I talk about my friendships?	Connections: A. Create short dialogues for new introductions of friends. B. Express opinions meeting new people.
Communities: A. How do you stay connected with your friends?	Communities: A. Create a dialogue between you and a friend you haven't seen in awhile.
INSTRUCTIONAL STRATEGIES <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accl: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accl: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice activities.</i> Use readings from textbook. Accl: <i>Students are given more target language readings especially in the culture segments of the unit.</i> Design and utilize PowerPoint/SMARTboard presentations Accl: <i>lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.</i> • Complete online exercises • Scaffold prior vocabulary • Utilize peer editing to further enhance writing skills. • Require students to access program Internet activities including but not limited to current news clips • Invite classroom speakers from target culture • Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning • Require students to participate in teacher-created web-based activities Create Total Physical Response (TPR) activities	

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language ***Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language***
- Dialogues and role-play activities in the target language ***Accl: Memorization of dialogues***
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: To provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (Student book, Workbooks, Communicative Activities, DVD, Audio CD)
- ***Accl: (I-Culture, Para Hispanohablantes)***
- Teacher materials: DVDs, Audio CD,
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages Spanish IV
Unit 2 <u>Vamos a hacer las maletas</u>
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.2 Describe various objects and people found at home and school. 1.1.4 Exchange basic information about events such as classes, meetings and meals. 1.1.5 Describe their favorite activities at home and school. 1.1.6 Express their likes and dislikes regarding various people, objects, categories and events present in their everyday environments. 1.2.2 Give and follow directions in order to travel from one location to another and ask questions for clarification. 1.2.3 Acquire goods and/or services through basic negotiations and exchange of monies. 2.1.1 Identify people and objects in their environments, based on oral and written descriptions. 2.1.2 Comprehend short conversations among peers and familiar adults on well-known topics, including their favorite activities at home or school. 2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.1 Give simple oral reports or presentations about family members and friends, objects, or common school and home activities in their everyday environments. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families, and their school activities. 3.3.7 Effectively use repetition, rephrasing and gestures to assist them in communicating their meaning in the target language. 4.2.1 Identify authentic products, such as those found in the target culture's homes and communities, and discuss their significance. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied 7.1.2 Demonstrate an awareness of the target language's phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.2 Access a wide variety of printed material that includes multicultural themes and character, fiction and nonfiction readings.

8.1.3 Identify and describe some cultural beliefs and perspectives relating to family, school, work and play across cultures.

8.1.5 Use new information and cultural awareness to compare and contrast their experiences with those of their peers in the target culture(s) and to identify with and respect peers in the target culture(s).

8.2.5 Use new information and perspectives to discuss the differences across cultures and begin to explain the reasons for such differences.

9.1.3 Review materials and/or media from the target language and culture for enjoyment and/or entertainment.

9.2.3 Demonstrate their target language skills while involved in community activities, including community service activities.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

Connecticut Frameworks Performance Standards (CSDE)

1.1.2, 1.1.4, 1.1.5, 1.1.6, 1.2.2, 1.2.3, 2.1.1, 2.1.2, 2.2.1, 2.2.5, 3.1.1, 3.1.3, 3.3.7, 4.2.1, 4.1.6, 4.2.6, 7.1.2, 7.2.2, 8.1.3, 8.1.5, 8.2.5, 9.1.3, 9.2.3, 9.2.7

Common Core State Standards for English Language Arts

In mastering the following standards in Spanish, students are expected to reinforce their understanding of such skills in English

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

SL 9.1.c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

L 9.2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 9.2.c. Spell correctly.

L 4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.

L 4.a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

L 4.c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.

L 4 d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L 5 a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L 5 b. Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or

phrase important to comprehension or expression.	
UNWRAPPED PERFORMANCE STANDARDS	
<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	written materials
3. Make	Informed hypotheses (written passages)
CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	

1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I use terms and words related to travel? B. How do I make travel plans? C. How do I identify people? D. How do I talk about present day activities? E. How do I discuss the future? F. How do I compare and contrast people and things?	Communication: A. Discuss travel in various locations (train station, airport, customs and hotel). B. Discuss future travel plans. C. Discuss present time activities related to travel. D. Express future travel plans to Spain. E. Role-play travel scenarios in a variety of places (train station, airport, customs and/or hotel) H. Create/Write a story or dialogue based on a variety of travel situations. I. Write questions related to various travel situations. Write comparisons of equality and inequality of people and things.
Culture: A. How does Barajas airport reflect Spanish customs? B. What is the nightlife like for “madrileñas”? C. How do Spaniards feel about employment?	Culture: A. Discuss the amenities in Barajas airport . B. Discuss the nightlife in Spain throughout the 4 seasons. C. Discuss how Spaniards feel about long term employment and read an example of a day in the life of a bell hop.
Comparisons: A. How does travel in the United States compare with Spain?	Comparisons: A. Compare the modes of travel available and how they are related to those when traveling in Spain.
Connections: A. How do English speakers use the different future tenses to indicate meaning?	Connections: A. Create a dialogue in the target language that includes both future tenses and compare to a similar one in English.
Communities: A. What modes of travel are available in the local community?	Communities: A. Investigate how to get in and around the local community using multi media sources and create a travel plan in the target language.

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

Model vocabulary, grammar and idiomatic expressions
 Incorporate video or audio segments from target cultures
 Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
 Create and utilize communicative activities
 Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
 Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
 Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
 Design and utilize PowerPoint/SMARTboard presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**

- Complete online exercises
- Scaffold prior vocabulary
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities

Create Total Physical Response (TPR) activities

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- **Assessments will be modified through the use of word banks and models for Academic classes**

Resources: To provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (Student book, Workbooks, Communicative Activities, DVD, Audio CD)
- ***Accl: (I-Culture, Para Hispanohablantes)***
- Teacher materials: DVDs, Audio CD,
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 3 ¿Cómo son los estudios en tu país?
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.2 Describe various objects and people found at home and school. 1.1.4 Exchange basic information about events such as classes, meetings and meals. 1.1.5 Describe their favorite activities at home and school. 1.1.6 Express their likes and dislikes regarding various people, objects, categories and events present in their everyday environments. 1.1.8 Recognize that there are often multiple ways to express an idea in the target language. 1.2.4 Work in groups to plan events and activities to be carried out in the target language, evaluate their efforts and identify ways to improve their communication in the target language. 1.2.5 Exchange thoughts about people, activities and events in their personal lives or communities 1.2.6 Find alternate methods of communication when they cannot express their intended message adequately. 2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.4 Create lists of items necessary to plan activities that might take place in their daily lives or in the target culture. 3.2.1 Make brief presentations to their class in the target language on topics of personal interest or topics that have been studied in other subject areas. 3.2.5 Write notes or short letters in the target language to peers in the target culture on topics of shared personal interest, including daily events and activities. 3.2.6 Prepare a diary of their daily activities and those of their families and friends in the target language. 3.2.7 Effectively use repetition, rephrasing and gestures to assist them in communicating their meaning in the target language. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.4 Use appropriate verbal and nonverbal behavior for daily activities among peers and for activities or contexts that include adult interaction.

4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied.

5.1.2 Use simple information from their world language class in their study of other subjects.

5.2.1 Acquire information from a variety of other subjects and integrate it into the world language classroom, comparing and evaluating the similarities and differences in information.

6.1.1 Use multimedia resources to access information regarding the target culture(s).

6.1.2 Recognize the various sources of information available only in the target language and culture(s), e.g., newspapers, websites, television, etc.

7.1.2 Demonstrate an awareness of the target language's phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.1 Understand how idiomatic expressions affect communication and reflect culture.

7.2.3 Use oral and written language to relate their own experiences and construct their own stories.

7.2.5 Produce coherent and accurate written work for a variety of purposes (e.g., lists, messages, short notes, journal entries).

8.2.3 Solicit their peers' opinions on aspects of culture through face- to-face contact or written exchanges and compare this information with how their peers in the target culture(s) view the same topic.

8.2.4 Use new information and perspectives to compare and contrast their experiences with those of their peers in the target culture(s).

8.2.6 Use new information and perspectives to identify universals of human experience across cultures and to demonstrate empathy and respect for the people(s) of other cultures.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

Connecticut Frameworks Performance Standards (CSDE) 1.1.2, 1.1.4, 1.1.5, 1.1.6, 1.1.8, 1.2.4, 1.2.5, 1.2.6 2.2.3, 2.2.5, 3.1.4, 3.2.1, 3.2.5, 3.2.6, 3.2.7, 4.1.6, 4.2.4, 4.2.6, 5.1.2, 5.2.1, 7.1.2, 7.2.1, 7.2.3, 7.2.5, 8.2.3, 8.2.4 , 8.2.6, 9.2.7

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions and feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)

2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)
CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. What do I need to know to be able to describe my daily routine? B. How do I find out about studying abroad? C. How do I express obligations and probability D. How do I express present activities E. How are the verbs ser and estar used in Spanish?	Communication: A. Use present tense reflexive verbs to talk about getting ready and your day at school, being a student, homework and people in a school and school buildings. B. Talk about studying abroad. C. Use <i>tener que</i> + infinitive, <i>haber que</i> and the infinitive, and <i>deber</i> and the infinitive to express obligation. Use <i>debe de ser</i> and <i>ha de tener</i> to express probability. D. Use the present tense to talk about roommate situations E. Use ser and estar to talk about the conditions at school and with a roommate , discuss careers and professions

Culture: A. What is the matriculation process in Peru? B. What is a semester in Peru like? C. What preparation for careers exists here in the United States and in Spanish- speaking countries ?	Culture: A. Describe what is necessary to matriculate abroad. B. Discuss the advantages of a semester in Peru? C. Talk about career choice and preparation for careers in the university and secondary schools.
Comparisons: A. How does schooling in Spanish- speaking countries differ from that of the United States B. How do reflexive verbs function? c. What are the uses of <i>ser</i> and <i>estar</i> ?	Comparisons: A. Compare school admissions abroad to those of the United States B. Differentiate between the reflexive and non- reflexive verbs . C. Use <i>ser</i> and <i>estar</i> . Ask where things are located in a school building
Connections: A. What are the similarities and differences between the daily routines for teachers and students in the United States and abroad?	Connections: A Create a Venn diagram of similarities and differences in daily life in the US and abroad
Communities: A. What would a semester in Peru be like?	Communities: A. Create a sample menu of popular Peruvian dishes.
INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accl: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accl: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice activities.</i> Use readings from textbook. Accl: <i>Students are given more target language readings especially in the culture segments of the unit.</i> Design and utilize PowerPoint/SMARTboard presentations Accl: <i>lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.</i> • Complete online exercises	

- Scaffold prior vocabulary
 - Utilize peer editing to further enhance writing skills.
 - Require students to access program Internet activities including but not limited to current news clips
 - Invite classroom speakers from target culture
 - Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
 - Require students to participate in teacher-created web-based activities
- Create Total Physical Response (TPR) activities

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language ***Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language***
- Dialogues and role-play activities in the target language ***Accl: Memorization of dialogues***
- Reading and listening comprehension activities
- ***Accl: Edit and revise writing pieces that contain multiple past tenses.***
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: To provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (Student book, workbooks)
- ***Accl: iCulture! (audio, video & practice)***
- Teacher materials: DVD program
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 4 <u>¡Qué grande es tu familia!</u>
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.1 Greet others and exchange essential information, including names, addresses, birthplaces, telephone numbers and e-mail addresses. 1.2.3 Acquire goods and/or services through basic negotiations and exchange of monies. 1.2.5 Exchange thoughts about people, activities and events in their personal lives or communities. 2.1.1 Identify people and objects in their environments, based on oral and written descriptions. 2.1.2 Comprehend short conversations among peers and familiar adults on well-known topics, including their favorite activities at home or school. 2.1.6 Comprehend brief notes on familiar topics, including daily activities at home or school. 2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.1 Give simple oral reports or presentations about family members and friends, objects, or common school and home activities in their everyday environments. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families, and their school activities. 3.2.1 Make brief presentations to their class in the target language on topics of personal interest or topics that have been studied in other subject areas. 3.2.5 Write notes or short letters in the target language to peers in the target culture on topics of shared personal interest, including daily events and activities. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.3 Participate in age-appropriate cultural activities, including, but not limited to adolescent games (e.g., cardboard, computer and outdoor games), sports-related activities, music, television and the Internet. 4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied. 4.3.1 Identify and analyze products and practices of the target culture (e.g., social,

economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

5.2.1 Acquire information from a variety of other subjects and integrate it into the world language classroom, comparing and evaluating the similarities and differences in information.

5.1.1 Use simple information learned in other subjects in their study of a world language.

5.1.3 Use new information and interdisciplinary awareness gained through world language study to expand their personal knowledge.

6.1.1 Use multimedia resources to access information regarding the target culture(s).

6.1.2 Recognize the various sources of information available only in the target language and culture(s), e.g., newspapers, websites, television, etc.

6.2.1 Use multiple media resources to expand their understanding of the target culture(s) and integrate it with their existing knowledge base.

6.2.2 Develop the necessary skills to use the Internet in order to gain greater access to the target culture(s).

7.1.2 Demonstrate an awareness of the target language's phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.2 Access a wide variety of printed material that includes multicultural themes and character, fiction and nonfiction readings.

8.1.3 Identify and describe some cultural beliefs and perspectives relating to family, school, work and play across cultures.

9.1.3 Review materials and/or media from the target language and culture for enjoyment and/or entertainment.

9.2.4 Review materials and/or media from the target language and culture for enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

1.1.1, 1.2.3, **1.2.5**, **2.1.1**, **2.1.2**, **2.1.6**, **2.2.3**, **2.2.5**, **3.1.1**, **3.1.3**, **3.2.1**, **3.2.5**, **4.1.6**, **4.2.3**, **4.2.6**, **4.3.1**, **5.2.1**, **5.1.1**, **5.1.3**, **6.1.1**, **6.1.2**, **6.2.1**, **6.2.2**, **7.1.2**, **7.2.2**, **8.1.3**, **9.1.3**, **9.2.4**

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	written materials
3. Make	Informed hypotheses (written passages)

CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I talk about events in the past? B. What information do I need to describe my home? C. How do I explain how long something has been occurring? D. How do I describe household chores?	Communication: A. Use vocabulary in context B. Describe what chores family members do in the home. C. Create a family tree. D. Create a blueprint of their home. E. Discuss meals.
Culture: A. What are the rites of passage in the Spanish-speaking world? B. What types of <i>sombreros</i> do people wear in Bolivia? C. What are some Inca traditions?	Culture: A. Identify different rites of passages in the Spanish-speaking world. B. Create a list of different sombreros worn in Bolivia. C. Discuss Inca traditions.
Comparisons: A. How is a Bolivian wedding different than a wedding in the US? B. What household chores are teenagers	Comparisons: A. Compare a traditional US wedding to that of Bolivia. B. Describe typical household chores in US

expected to do in Spanish-speaking countries? C. How are the two past tenses, the preterite and the imperfect, different? D. What are the differences between the two verbs “to know” in Spanish?	and Bolivia. C. Identify when to use the preterite vs. the imperfect D. Prepare a list of the uses of each verb to know.
Connections: A. What are family dynamics like throughout the Spanish speaking world? B. What are some similarities and differences in wedding traditions in US vs. Bolivia?	Connections: A. Evaluate the differences in American/Bolivian family households B. Create a Venn-Diagram of similarities and differences between weddings in US and Bolivia
Communities: A. Compare the traditions in Bolivia to the traditions of the American culture.	Communities: A. What local activities and events encourage family interaction?
INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accl: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accl: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice activities.</i> Use readings from textbook. Accl: <i>Students are given more target language readings especially in the culture segments of the unit.</i> Design and utilize PowerPoint/SMARTboard presentations Accl: <i>lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.</i> • Complete online exercises • Scaffold prior vocabulary • Utilize peer editing to further enhance writing skills. • Require students to access program Internet activities including but not limited to current news clips • Invite classroom speakers from target culture • Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning • Require students to participate in teacher-created web-based activities Create Total Physical Response (TPR) activities	

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language ***Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language***
- Dialogues and role-play activities in the target language ***Accl: Memorization of dialogues***
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources:

In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- Aventura 4
- Student materials (Student book, workbooks)
- ***Accl: iCulture! (audio, video & practice)***
- Teacher materials: DVD program
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 5 ¡Cerreemos el trato!
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
1.2.1 Exchange information with peers and the teacher (both face-to-face and in writing) about events in their everyday lives and experiences from their past. 1.3.3 Participate in culturally appropriate exchanges that reflect social amenities such as expressing gratitude, extending and receiving invitations, apologizing and communicating preferences. 2.1.7 Comprehend the principal message of highly illustrated texts in which cognates are used, including stories, newspaper articles and advertisements. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families and their school activities. 4.1.4 Participate in age-appropriate cultural activities, such as games, songs, birthday celebrations, storytelling, dramatizations or role-playing of the target culture. 4.2.5 Observe, identify and discuss patterns of behavior or interaction that are typical of their peer group in the target culture. 5.2.3 Use new information and critical thinking gained through world language study to expand their personal knowledge. 7.2.1 Understand how idiomatic expressions affect communications and reflect culture. 8.1.5 Use new information and cultural awareness to compare and contrast their experiences with those of their peers in the target culture(s) and to identify with and respect peers in the target culture(s). 9.2.1 Discuss their families, school experiences, free-time activities and current events in the target language in oral or written form.
Connecticut Frameworks Performance Standards (CSDE) 1.2.1, 1.3.3, 2.1.7, 3.1.3, 4.1.4, 4.2.5, 5.2.3, 7.2.1, 8.1.5, 9.2.1
Common Core State Standards for English Language Arts In mastering the following standards in Spanish, students are expected to reinforce their understanding of such skills in English SPEAKING AND LISTENING STANDARD: SL LANGUAGE STANDARD: L SL 9.1.c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

L 9.2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 9.2.c. Spell correctly.

L 4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.

L 4.a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

L 4.c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.

L 4 d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L 5 a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L 5 b. Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)
CS3	
1. Present	Topics of personal interest

2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and Integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information

enables one to fully participate as a citizen of the world. 2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures. 3. Language is a tool that can be used to connect with other disciplines and acquire information. 4. By comparing languages and cultures, students develop insights into their own language and culture. 5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.	
<u>Essential Questions</u> <i>Teacher's guiding questions</i> 1. What does it mean to communicate and how do I communicate in my target language? 2. What is culture and how do I learn more about other cultures? 3. How can I use my foreign language to increase my understanding of other disciplines? 4. Why is it important to make cultural and linguistic comparisons? 5. Where can I use my foreign language outside of the classroom?	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I discuss banking and business? B. How do I discuss trade and job opportunities in Spanish-speaking countries? C. How do I talk about situations that have and had happened? D. How do I describe actions? E. How do I discuss trade and job opportunities in Spanish-speaking countries F. How do I make generalized statements?	Communication: A. Use vocabulary associated with banking and business. B. Create conversations based on banking (checking and savings accounts) and business scenarios. C. Create dialogues and writing samples that use the <i>presente perfecto y pluscuamperfecto</i>. D. Use <i>Gustar</i> style verbs to make generalized statements about business topics.

Culture: A. How are smaller businesses viewed and supported in the Mexican economy? B. What are some common foods in Mexico? C. How was Mexico City founded?	Culture: A. Discuss the impact of “Pymes” in Mexico on the economy of the country. B. Describe common Mexican foods and ingredients. C. Describe how Mexico City was founded by the Aztecs and how Hernan Cortez shaped the city later.
Comparisons: A. How are object pronouns used in Spanish and English? B. How do I use the <i>presente perfecto</i> y <i>el pluscuamperfecto</i> to describe past actions?	Comparisons: A. Compare and contrast the placement of double object pronouns in Spanish and English. B. Compare and contrast the grammatical structures for <i>presente perfecto</i> y <i>el pluscuamperfecto</i> .
Connections: A. What cities do you know in Mexico? B. What are some current happenings in Mexico? C. What are some typical dishes that your family prepares? D. What are some special meals that are prepared for holidays?	Connections: A. Investigate the location of Mexico’s principals cities. B. Present an article on a current event in Mexico. C. Research typical meals that are prepared in the US and Mexico. D. Research meals that are prepared for holidays.
Communities: A. What small businesses are owned or run by people from Mexico?	Communities: A. Investigate the location of local Mexican restaurants and businesses and present them using multimedia sources.
INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accl: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accl: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice activities.</i> Use readings from textbook. Accl: <i>Students are given more target language readings</i>	

especially in the culture segments of the unit.

Design and utilize PowerPoint/SMARTboard presentations ***Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.***

- Complete online exercises
- Scaffold prior vocabulary
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities

Create Total Physical Response (TPR) activities

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language ***Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language***
- Dialogues and role-play activities in the target language ***Accl: Memorization of dialogues***
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- Culture comparison charts ***Accl: Creation of multiple charts that document cultural similarities and differences.***
- ***Accl: Record a Podcast and create a worksheet with questions for classmates.***
- ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources: To provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (student book, workbooks, communicative activities, textbook DVD)
- ***Accl: ICulture, Para Hispanohablantes***
- Teacher materials: DVDs (Listening activities, ICulture website, communicative activities)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 6 ¡Cuide su salud!
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.2 Describe various objects and people found while traveling. 1.1.4 Exchange basic information about events such a travel. 1.1.5 Describe their favorite activities at home and school. 1.1.6 Express their likes and dislikes regarding various people, objects, categories and events present in their everyday environments. 1.2.2 Give and follow directions in order to travel from one location to another and ask questions for clarification. 1.2.3 Acquire goods and/or services through basic negotiations and exchange of monies. 2.1.1 Identify people and objects in their environments, based on oral and written descriptions. 2.1.2 Comprehend short conversations among peers and familiar adults on well-known topics, including their favorite activities at home or school. 2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.1 Give simple oral reports or presentations about family members and friends, objects, or common school and home activities in their everyday environments. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families, and their school activities. 3.3.7 Effectively use repetition, rephrasing and gestures to assist them in communicating their meaning in the target language. 4.2.1 Identify authentic products, such as those found in the target culture’s homes and communities, and discuss their significance. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied 7.1.2 Demonstrate an awareness of the target language’s phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.2 Access a wide variety of printed material that includes multicultural themes and character, fiction and nonfiction readings.

8.1.3 Identify and describe some cultural beliefs and perspectives relating to family, school, work and play across cultures.

8.1.5 Use new information and cultural awareness to compare and contrast their experiences with those of their peers in the target culture(s) and to identify with and respect peers in the target culture(s).

8.2.5 Use new information and perspectives to discuss the differences across cultures and begin to explain the reasons for such differences.

9.1.3 Review materials and/or media from the target language and culture for enjoyment and/or entertainment.

9.2.3 Demonstrate their target language skills while involved in community activities, including community service activities.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

Connecticut Frameworks Performance Standards (CSDE)

1.1.2, 1.1.4, 1.1.5, 1.1.6, 1.2.2, 1.2.3, 2.1.1, 2.1.2, 2.2.1, 2.2.5, 3.1.1, 3.1.3, 3.3.7, 4.2.1, 4.1.6, 4.2.6, 7.1.2, 7.2.2, 8.1.3, 8.1.5, 8.2.5, 9.1.3, 9.2.3, 9.2.7

Common Core State Standards for English Language Arts

In mastering the following standards in French, students are expected to reinforce their understanding of such skills in English

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

SL 9.1.c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

L 9.2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 9.2.c. Spell correctly.

L 4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.

L 4.a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

L 4.c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.

L 4 d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L 5 a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L 5 b. Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or

phrase important to comprehension or expression.	
UNWRAPPED PERFORMANCE STANDARDS	
<u><i>Skills</i></u> <i>What students need to be able to do</i>	<u><i>Concepts</i></u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)
CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	

1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
3. Language is a tool that can be used to connect with other disciplines and acquire information.
4. By comparing languages and cultures, students develop insights into their own language and culture.
5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
2. What is culture and how do I learn more about other cultures?
3. How can I use my foreign language to increase my understanding of other disciplines?
4. Why is it important to make cultural and linguistic comparisons?
5. Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I talk about health? B. What do I need to know to be able to identify body parts ? C. How are making requests, suggestions and demands different from statements ? D. How do indicate ownership ?	Communication: A. Describe health symptoms of yourself or of people in an emergency room or waiting room in a doctor's office. B. Describe aspects of daily routine that contribute to good health C. Give commands that a doctor or dentist would give to their patients D. Write about symptoms and treatments for a variety of ailments .
Culture: A. What are some of the natural attractions of Chile? B. How do home remedies and the sale of medicine differ within Chile's boundaries? C. What are some natural remedies for indigestion, high cholesterol and the common cold. D. How are expressing orders, desires and giving advice different in Spanish?	Culture: A. Discuss the geography of Chile B. Read about the role of alternative medicine in cities and towns of Chile. C. Find resources for natural remedies and suggest some for some ailments. D. Use the subjunctive mood to give orders, express desires and to give advice
Comparisons: A. What is the medical industry like in Chile; what are the attitudes toward natural medicine and cold remedies the same or different in big cities and small towns? B. Does the population of the United States use more or less natural medicine than the population of Mexico or Central America?	Comparisons: A. Compare and contrast the attitudes toward natural medicine and cold remedies between small towns and cities. B. Compare the use of natural medicine between the US and Mexico and Central America. .
Connections: A. What questions do you have about Chile? B. How do you order, express desires and give advice in English? C. Which stores or restaurants provide healthy products and foods where you live? D. What is the peso chileno E. What kind of life was led by the Chilean poet Pablo Neruda? F. What are the top ten recommendations for being healthy?	Connections: A. Create a list of questions you have about this country. B. Create a set of orders, desires and sentences giving advice. C. Research and discuss various stores and restaurants that provide healthy products and food where you live. D. Research the currency of other Spanish- speaking countries. E. Make a timeline of the events and works of Pablo Neruda F. Create posters with top ten recommendations for being healthy present the information to the class.

Communities: A. How does the community take care of their health?	Communities: A. Discuss health practices of the community.
INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class. Create and utilize communicative activities Support peer teaching. Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching. Design various practice activities for vocabulary acquisition and retention. Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities. Use readings from textbook. Accl: Students are given more target language readings especially in the culture segments of the unit. Design and utilize PowerPoint/SMARTboard presentations Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance. • Complete online exercises • Scaffold prior vocabulary • Utilize peer editing to further enhance writing skills. • Require students to access program Internet activities including but not limited to current news clips • Invite classroom speakers from target culture • Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning • Require students to participate in teacher-created web-based activities Create Total Physical Response (TPR) activities	
Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:	
• Writing prompts in the target language Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language • Dialogues and role-play activities in the target language Accl: Memorization of dialogues • Reading and listening comprehension activities • Vocabulary and structure quizzes • Cloze activities • Summative performance assessments (oral or in writing) • Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis) • Culture comparison charts Accl: Creation of multiple charts that document cultural	

similarities and differences.

· ***Assessments will be modified through the use of word banks and models for Academic classes***

Resources:

In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (student book, workbooks, communicative activities, textbook DVD)
- ***Accl: ICulture, Para Hispanohablantes***
- Teacher materials: DVDs (Listening activities, ICulture website, communicative activities)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 7 ¿Conoces mi ciudad?
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.2 Describe various objects and people found at home and school. 1.1.4 Exchange basic information about events such as classes, meetings and meals. 1.1.5 Describe their favorite activities at home and school. 1.1.6 Express their likes and dislikes regarding various people, objects, categories and events present in their everyday environments. 1.2.2 Give and follow directions in order to travel from one location to another and ask questions for clarification. 1.2.3 Acquire goods and/or services through basic negotiations and exchange of monies. 2.1.1 Identify people and objects in their environments, based on oral and written descriptions. 2.1.2 Comprehend short conversations among peers and familiar adults on well-known topics, including their favorite activities at home or school. 2.2.1 Comprehend the main ideas when listening to peers and familiar adults discuss topics of personal interest. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.1 Give simple oral reports or presentations about family members and friends, objects, or common school and home activities in their everyday environments. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families, and their school activities. 3.3.7 Effectively use repetition, rephrasing and gestures to assist them in communicating their meaning in the target language. 4.2.1 Identify authentic products, such as those found in the target culture's homes and communities, and discuss their significance. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied 7.1.2 Demonstrate an awareness of the target language's phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.2 Access a wide variety of printed material that includes multicultural themes and character, fiction and nonfiction readings.

8.1.3 Identify and describe some cultural beliefs and perspectives relating to family, school, work and play across cultures.

8.1.5 Use new information and cultural awareness to compare and contrast their experiences with those of their peers in the target culture(s) and to identify with and respect peers in the target culture(s).

8.2.5 Use new information and perspectives to discuss the differences across cultures and begin to explain the reasons for such differences.

9.1.3 Review materials and/or media from the target language and culture for enjoyment and/or entertainment.

9.2.3 Demonstrate their target language skills while involved in community activities, including community service activities.

9.2.7 Demonstrate self-knowledge as well as understanding of others in areas of common interest through the target language.

Connecticut Frameworks Performance Standards (CSDE)

1.1.2, 1.1.4, 1.1.5, 1.1.6, 1.2.2, 1.2.3, 2.1.1, 2.1.2, 2.2.1, 2.2.5, 3.1.1, 3.1.3, 3.3.7, 4.2.1, 4.1.6, 4.2.6, 7.1.2, 7.2.2, 8.1.3, 8.1.5, 8.2.5, 9.1.3, 9.2.3, 9.2.7

Common Core State Standards for English Language Arts

In mastering the following standards in Spanish, students are expected to reinforce their understanding of such skills in English

SPEAKING AND LISTENING STANDARD: SL

LANGUAGE STANDARD: L

SL 9.1.c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

L 9.2 Demonstrate command of the conventions of standard capitalization, punctuation, and spelling when writing.

L 9.2.c. Spell correctly.

L 4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9-10 reading and content, choosing flexibly from a range of strategies.

L 4.a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

L 4 b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

L 4.c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.

L 4 d Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L 5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L 5 a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L 5 b. Analyze nuances in the meaning of words with similar denotations.

L 6 Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or

phrase important to comprehension or expression.	
UNWRAPPED PERFORMANCE STANDARDS	
<u><i>Skills</i></u> <i>What students need to be able to do</i>	<u><i>Concepts</i></u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)
CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)

CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media
<u>Big Ideas</u> <i>Student's statements of enduring ideas</i> 1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world. 2. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures. 3. Language is a tool that can be used to connect with other disciplines and acquire information. 4. By comparing languages and cultures, students develop insights into their own language and culture. 5. The study of a foreign language allows students to participate in multilingual communities at home and around the world.	
<u>Essential Questions</u> <i>Teacher's guiding questions</i> 1. What does it mean to communicate and how do I communicate in my target language? 2. What is culture and how do I learn more about other cultures? 3. How can I use my foreign language to increase my understanding of other disciplines? 4. Why is it important to make cultural and linguistic comparisons?	

5. Where can I use my foreign language outside of the classroom?	
Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I use terms and words associated with shopping in the city? B. How do I identify foods and clothing items? C. How do I discuss hypothetical situations? D. How do I talk about situations that would have happened? E. How do I describe actions? F. How do I discuss issues related to living in a big city? G. How do I understand cultural perspectives of Argentina?	Communication: A. Discuss city vocabulary B. Discuss street vocabulary C. Describe various fabrics C. Create a dialogue around getting familiar with a new city. D. Describe fashion E. Utilize the subjunctive with adverbial clauses F. Create conversation between a sales clerk and customer in a clothing store. G. Create a shopping list that you need to prepare for a party.
Culture: A. How is shopping unique in Buenos Aires, Argentina? B. What are some cultural perspectives of Argentina?	Culture: A. Research and compare US shopping in New York or other big cities to that of Buenos Aires, Argentina. B. Evaluate different cultural perspectives of Argentina.
Comparisons: A. How do I compare the use of adverbial clauses with and without the subjunctive? B. How do I use present subjunctive?	Comparisons: A. Create a T-chart that identifies the adverbial clauses. B. Create a list of verbs that are commonly used as the independent clause.
Connections: A. What are some famous sites, foods and people of Argentina? B. What are unique foods served throughout the Spanish speaking world?	Connections: A. Create a multi-media presentation about famous sites, foods and/or people in Argentina. B. Make a list of Spanish speaking countries that have unique cuisines.
Communities: A. What type of government assisted housing programs do we offer in the US? B. What are the “do’s” and “don’t” of today’s fashion?	Communities: A. Make a list of programs your state offers to assist families in buying homes. B. Write an article on the do’s and don’t of today’s fashions for a current magazine.

INSTRUCTIONAL STRATEGIES: *Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:*

Model vocabulary, grammar and idiomatic expressions
 Incorporate video or audio segments from target cultures
 Facilitate classroom discussions that examine and compare cultural differences. **Accl: Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.**
 Create and utilize communicative activities
 Support peer teaching. **Accl: Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.**
 Design various practice activities for vocabulary acquisition and retention. **Accl: Students are given additional vocabulary and higher level Depth of Knowledge practice activities.**
 Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**
 Design and utilize PowerPoint/SMARTboard presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**

- Complete online exercises
- Scaffold prior vocabulary
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities

Create Total Physical Response (TPR) activities

Assessments: to understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- **Assessments will be modified through the use of word banks and models for Academic classes**

Resources:

In order to provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (student book, workbooks, communicative activities, textbook DVD)
- ***Accl: ICulture, Para Hispanohablantes***
- Teacher materials: DVDs (Listening activities, ICulture website, communicative activities)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)

World Languages: Spanish IV
Unit 8 Hispanoamérica : ¡Qué diversidad! Puerto Rico
Connecticut Frameworks Content Standards (CSDE) CONTENT STANDARD 1: Communication (Interpersonal Mode) CONTENT STANDARD 2: Communication (Interpretive Mode) CONTENT STANDARD 3: Communication (Presentational Mode) CONTENT STANDARD 4: Culture CONTENT STANDARD 5: Connections (Interdisciplinary Mode) CONTENT STANDARD 6: Connections (Interdisciplinary Mode) CONTENT STANDARD 7: Comparisons Among Languages CONTENT STANDARD 8: Comparisons Among Cultures CONTENT STANDARD 9: Communities
Connecticut Frameworks Performance Standards (CSDE) 1.1.1 Greet others and exchange essential information, including names, addresses, birthplaces, telephone numbers and e-mail addresses. 1.2.3 Acquire goods and/or services through basic negotiations and exchange of monies. 1.2.5 Exchange thoughts about people, activities and events in their personal lives or communities. 2.1.1 Identify people and objects in their environments, based on oral and written descriptions. 2.1.2 Comprehend short conversations among peers and familiar adults on well-known topics, including their favorite activities at home or school. 2.1.6 Comprehend brief notes on familiar topics, including daily activities at home or school. 2.2.3 Work individually to collect data on familiar topics from various print, digital and electronic resources. 2.2.5 Comprehend the basic content of written materials selected by the teacher on the basis of topical familiarity, e.g., personal letters, e-mail, websites, pamphlets, advertisements and illustrated newspaper and magazine articles. 3.1.1 Give simple oral reports or presentations about family members and friends, objects, or common school and home activities in their everyday environments. 3.1.3 Write short informal notes in which they describe or provide information about themselves, their friends and families, and their school activities. 3.2.1 Make brief presentations to their class in the target language on topics of personal interest or topics that have been studied in other subject areas. 3.2.5 Write notes or short letters in the target language to peers in the target culture on topics of shared personal interest, including daily events and activities. 4.1.6 Recognize simple themes, ideas or perspectives of the target culture. 4.2.3 Participate in age-appropriate cultural activities, including, but not limited to adolescent games cardboard, board, computer and outdoor games), sports-related activities, music, television and the Internet. 4.2.6 Identify, discuss, analyze and evaluate themes, ideas and perspectives that are related to the practices and products being studied. 4.3.1 Identify and analyze products and practices of the target culture (e.g., social,

economic, legal and political), and explore the relationships between these products and practices and the perspectives of the culture.

5.2.1 Acquire information from a variety of other subjects and integrate it into the world language classroom, comparing and evaluating the similarities and differences in information.

5.1.1 Use simple information learned in other subjects in their study of a world language.

5.1.3 Use new information and interdisciplinary awareness gained through world language study to expand their personal knowledge.

6.1.1 Use multimedia resources to access information regarding the target culture(s).

6.1.2 Recognize the various sources of information available only in the target language and culture(s), e.g., newspapers, websites, television, etc.

6.2.1 Use multiple media resources to expand their understanding of the target culture(s) and integrate it with their existing knowledge base.

6.2.2 Develop the necessary skills to use the Internet in order to gain greater access to the target culture(s).

7.1.2 Demonstrate an awareness of the target language's phonetic and writing systems and how they differ from the phonetic and writing systems in the English language.

7.2.2 Access a wide variety of printed material that includes multicultural themes and character, fiction and nonfiction readings.

8.1.3 Identify and describe some cultural beliefs and perspectives relating to family, school, work and play across cultures.

9.1.3 Review materials and/or media from the target language and culture for enjoyment and/or entertainment.

9.2.4 Review materials and/or media from the target language and culture for enjoyment.

Connecticut Frameworks Performance Standards (CSDE)

1.1.1, 1.2.3, **1.2.5**, **2.1.1**, **2.1.2**, **2.1.6**, **2.2.3**, **2.2.5**, **3.1.1**, **3.1.3**, **3.2.1**, **3.2.5**, **4.1.6**, **4.2.3**, **4.2.6**, **4.3.1**, **5.2.1**, **5.1.1**, **5.1.3**, **6.1.1**, **6.1.2**, **6.2.1**, **6.2.2**, **7.1.2**, **7.2.2**, **8.1.3**, **9.1.3**, **9.2.4**

UNWRAPPED PERFORMANCE STANDARDS

<u>Skills</u> <i>What students need to be able to do</i>	<u>Concepts</u> <i>What students need to know about</i>
CS1	
1. Find	Alternate methods of communication
2. Exchange	Information (current, past events, hopes & aspirations)
3. Share	Personal reactions & feelings (literature)
CS2	
1. Understand	Main ideas, themes, details (television, radio)
2. Comprehend	Written materials
3. Make	Informed hypotheses (written passages)

CS3	
1. Present	Topics of personal interest
2. Summarize, describe	Plots & characters
3. Prepare	Oral, written presentations (current/historical events)
4. Describe/express/analyze	Opinions (literature, radio, music, film, art, etc.)
5. Use	Target language dictionary
CS4	
1. Participate	Age-appropriate activities (games, sports, etc.)
2. Identify, analyze, evaluate	Themes, ideas, perspectives, target culture
3. Identify, experience, read, discuss	Expressive cultural products (video, art, etc.)
CS5	
1. Acquire	Complex abstract information (interdisciplinary)
2. Use	Interdisciplinary information
CS6	
Use and integrate	Multimedia sources
CS7	
CS8	
1. Analyze	World perspectives of U.S.
CS9	
1. Use/enjoy	Cultural media

Big Ideas

Student's statements of enduring ideas

1. Communicating in languages other than English by engaging in conversations, understanding and interpreting spoken and written language, and presenting information enables one to fully participate as a citizen of the world.
1. A knowledge and understanding of other cultures is gained through examining the products, practices, and perspectives of those cultures.
1. Language is a tool that can be used to connect with other disciplines and acquire information.
1. By comparing languages and cultures, students develop insights into their own language and culture.

The study of a foreign language allows students to participate in multilingual communities at home and around the world.

Essential Questions

Teacher's guiding questions

1. What does it mean to communicate and how do I communicate in my target language?
1. What is culture and how do I learn more about other cultures?
1. How can I use my foreign language to increase my understanding of other disciplines?
1. Why is it important to make cultural and linguistic comparisons?

Where can I use my foreign language outside of the classroom?

Unit Essential Questions	Learning Objectives The students will be able to:
Communication: A. How do I express actions that are dependent upon another condition? B. How do I talk about possibilities, probabilities and hypothetical situations C. How do I make affirmative and negative statements? D. How do I talk about geography, the environment and current events? E.	Communication: A. Use the conditional tense to say what you would do in various situations. Say which political candidates you would vote for in an election B. say what someone would do B. Create a healthy living regimen including diet and exercise. C. Formulate a healthy eating plan using the food pyramid.
Culture: A. What is the nature of the indigenous population of Puerto Rico? B. What factors contribute to the increase of alcoholism among women?	Culture: A. Name two tribes that lived in Puerto Rico. B. Describe and locate thermal springs in Latin America C

Comparisons A. How do the rights of the citizens of Puerto Rico differ from those of residents of individual states? B. Does the US have an official language? C. When do I use the present perfect subjunctive?	Comparisons: A. Compare the rights of the people of Puerto Rico with those of individual states in the US. B. Read about the language struggles in Puerto Rico. C. Compare the use of the indicative to that of the subjunctive.
Connections: A. What makes the history of Puerto Rico interesting? B. What information about Central and South America and its geography and history are important? C. What types of governments does Spanish America have? D. How is the rich heritage of the indigenous North American indigenous civilizations preserved? E. What is Alcoholics Anonymous and what are the symptoms of alcoholism?	Connections: A. Explain the history of Puerto Rico B. List important geographical and historical features. C. Give examples of types of governments in Spanish America. D. Visit the Alcoholics Anonymous website (in Spanish) to get information about alcoholism and available services.
Communities: A. Is there any evidence of Puerto Rican culture in your community? B. Are there local environmental groups where you live? C. Are there any environmental issues in your community?	Communities: A. State where there is evidence of Puerto Rican culture in your community? B. Name the local environmental groups in your community. C. List environmental issues in the community and write sentences about what caused them using the passive voice.
INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i>	
Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accl: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accl: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accl: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice</i>	

activities.

Use readings from textbook. **Accl: Students are given more target language readings especially in the culture segments of the unit.**

Design and utilize PowerPoint/SMARTboard presentations **Accl: lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.**

- Complete online exercises
- Scaffold prior vocabulary
- Utilize peer editing to further enhance writing skills.
- Require students to access program Internet activities including but not limited to current news clips
- Invite classroom speakers from target culture
- Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning
- Require students to participate in teacher-created web-based activities

Create Total Physical Response (TPR) activities

Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following:

- Writing prompts in the target language **Accl: Rubrics adjusted to include more requirements demonstrating independent use of the language**
- Dialogues and role-play activities in the target language **Accl: Memorization of dialogues**
- Reading and listening comprehension activities
- Vocabulary and structure quizzes
- Cloze activities
- Summative performance assessments (oral or in writing)
- Culture comparison charts **Accl: Creation of multiple charts that document cultural similarities and differences.**
- Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
- **Assessments will be modified through the use of word banks and models for Academic classes**

Resources: To provide students with the best language outcome, teachers will employ the following resources, available from both teacher materials and the Internet:

- *Aventura 4*
- Student materials (student book, workbooks, communicative activities, textbook DVD)
- **Accl: ICulture, Para Hispanohablantes**
- Teacher materials: DVDs (Listening activities, ICulture website, communicative activities)
- Audio CDs (testing and audio program)
- Depth of Knowledge (Webb's Depth of Knowledge tools)



Spanish IV Revision

Approval requested for course revision

Bristol Board of Education Student Achievement Committee

May 21, 2014

Pamela M. Brisson, Ed.D

Supervisor of Humanities & World Languages

Rationale

- Outdated text led to review for Spanish program
 - since 2011, Spanish 1-3 revised and implemented
- Spanish IV natural extension

Standards

- CT State Standards for World Languages
 - **Communication**
 - interpersonal
 - interpretive
 - presentational
 - **Culture**
 - **Connections**
 - **Comparisons**
 - languages
 - cultures
 - **Communities**

English Language Arts Common Core State Standards

—Supports

- **Reading**
- **Writing**
- **Speaking & Listening**
- **Language**

—Transfers to other courses

Result

- increased rigor in grammatical concepts and reading & writing production
- more non fiction text in the target language
- more analysis than ever before
- updated cultural connections

Differentiating: Academic & Accelerated

Communication: A. How do I talk about health? B. What do I need to know to be able to identify body parts? C. How are making requests, suggestions and demands different from statements? D. How do indicate ownership?	Communication: A. Describe health symptoms of yourself or of people in an emergency room or waiting room in a doctor's office. B. Describe aspects of daily routine that contribute to good health. C. Give commands that a doctor or dentist would give to their patients. D. Write about symptoms and treatments for a variety of ailments.	INSTRUCTIONAL STRATEGIES: <i>Based on our philosophy for student learning in World Languages and our knowledge of effective instruction, teachers will:</i> Model vocabulary, grammar and idiomatic expressions Incorporate video or audio segments from target cultures Facilitate classroom discussions that examine and compare cultural differences. Accel: <i>Accelerated students play the roles of facilitators during classroom discussions. Students can also be assigned group discussion topics, with the goal of presenting discussion results to the class.</i> Create and utilize communicative activities Support peer teaching. Accel: <i>Students create mini lessons based on an assigned topic, after self teaching to teach the rest of the class. In split classes, accelerated students also can have the opportunity to act as a peer teacher, after self teaching.</i> Design various practice activities for vocabulary acquisition and retention. Accel: <i>Students are given additional vocabulary and higher level Depth of Knowledge practice activities.</i> Use readings from textbook. Accel: <i>Students are given more target language readings especially in the culture segments of the unit.</i> Design and utilize PowerPoint/SMARTboard presentations. Accel: <i>lessons differ in structure and in delivery. Accelerated students are introduced to material (especially grammar concepts) in a way to require them to develop logical conclusions with less teacher guidance.</i> • Complete online exercises • Scaffold prior vocabulary • Utilize peer editing to further enhance writing skills. • Require students to access program Internet activities including but not limited to current news clips • Invite classroom speakers from target culture • Make interdisciplinary (i.e.: Math, Social Sciences, English) connections to reinforce learning • Require students to participate in teacher-created web-based activities Create Total Physical Response (TPR) activities Assessments: To understand the strengths and weaknesses of our students, teachers will assess and provide feedback to students about the following: - Writing prompts in the target language Accel: <i>Rubrics adjusted to include more requirements demonstrating independent use of the language</i> - Dialogues and role-play activities in the target language Accel: <i>Memorization of dialogues</i> - Reading and listening comprehension activities - Vocabulary and structure quizzes - Cloze activities - Summative performance assessments (oral or in writing) - Technology based activities (i.e. Power Point, Voice Thread, Voki and Wikis)
Culture: A. What are some of the natural attractions of Chile? B. How do home remedies and the sale of medicine differ within Chile's boundaries? C. What are some natural remedies for indigestion, high cholesterol and the common cold? D. How are expressing orders, desires and giving advice different in Spanish?	Culture: A. Discuss the geography of Chile. B. Read about the role of alternative medicine in cities and towns of Chile. C. Find resources for natural remedies and suggest some for some ailments. D. Use the subjunctive mood to give orders, express desires and to give advice	
Comparisons: A. What is the medical industry like in Chile; what are the attitudes toward natural medicine and cold remedies the same or different in big cities and small towns? B. Does the population of the United States use more or less natural medicine than the population of Mexico or Central America?	Comparisons: A. Compare and contrast the attitudes toward natural medicine and cold remedies between small towns and cities. B. Compare the use of natural medicine between the US and Mexico and Central America.	
Connections: A. What questions do you have about Chile? B. How do you order, express desires and give advice in English? C. Which stores or restaurants provide healthy products and foods where you live? D. What is the peso chileno? E. What kind of life was led by the Chilean poet Pablo Neruda? F. What are the top ten recommendations for being healthy?	Connections: A. Create a list of questions you have about this country. B. Create a set of orders, desires and sentences giving advice. C. Research and discuss various stores and restaurants that provide healthy products and food where you live. D. Research the currency of other Spanish-speaking countries. E. Make a timeline of the events and works of Pablo Neruda F. Create posters with top ten recommendations for being healthy present the information to the class.	

Financial Implications

- Staff to write curriculum \$600
- Staff to build implementation guide \$1,000
- New textbook \$15,658.50

Thank You

- *To the teachers who worked on behalf of Bristol students to create this revision:*
 - *Kathy Archibald, BCHS*
 - *Andrea Rajotte, BEHS*



Questions?



**Bristol Public Schools
Office of Teaching & Learning**

DEPARTMENT: Mathematics

COURSE: Pre-Calculus

COURSE DESCRIPTION

This course is the fourth course in the college preparatory mathematics sequence. It is a prerequisite for the analytic geometry and calculus course offered by colleges. Topics studied are algebraic functions, logarithms and exponential functions, trigonometric functions and conics. All topics studied will involve the use of a TI-83+ or TI-84+ graphing calculator. Students enrolled in this class must take the common mid-term and final assessment for Pre-Calculus Academic.

DEPARTMENT PHILOSOPHY

The philosophy of the mathematics department is to develop mathematically literate and productive students who can effectively and efficiently apply mathematics in their lives to make informed decisions about the world around them. To be mathematically literate, one must understand major mathematics concepts, possess computational facility and have the ability to apply these understandings to situations in daily life. Making connections between mathematics and other disciplines is key to the appropriate application of mathematics skills and concepts to solve problems. The ability to read, discuss, and write within the discipline of mathematics is an integral skill that supports mathematical understanding, reasoning and communication. The opportunity to think critically and creatively to solve problems is important to deepen mathematical knowledge and foster innovation. A rich mathematical experience is essential to provide the foundational knowledge and skills that prepare students to be mathematically literate, productive citizens.

The Bristol mathematics curriculum focuses on high expectations for **all** students and provides a balanced approach to mathematics education, placing equal importance on conceptual understanding, computational and procedural fluency and problem solving through the use of a variety of strategies, tools and technologies. The mathematics curriculum is responsive to the individual needs of students. While proving a structure tied to the Common Core State Standards in Connecticut, it allows for classroom experiences, additional supports and enrichment ensuring students' access to the content at an appropriate level of challenge.

Unit Organization:	Instruction focuses in critical areas:
Unit 1 – Functions and Graphs	Critical Area 1: Functions and Graphs In earlier grades, students define, evaluate, and compare functions, and use them to model relationships between quantities. In this unit, students will utilize function notation to perform operations with functions and extend the concepts of domain and range. Students expand their experience with functions to include more specialized functions – absolute value, step, and those that are piecewise-defined. In this unit, students compare the key characteristics of function families, explore symmetry of graphs, as well as find and graph inverses of functions. They interpret functions given graphically, numerically, symbolically, and verbally, translate between representations.
Unit 2 – Polynomial and Rational Functions	Critical Area 2: Polynomial, Rational, and Radical Relationships This unit develops the structural similarities between the system of polynomials and the system of integers. Students draw on analogies between polynomial arithmetic and base-ten computation, focusing on properties of operations, particularly the distributive property. Students connect multiplication of polynomials with multiplication of multi-digit integers, and division of polynomials with long division of integers. Students identify zeros of polynomials and make connections between zeros of polynomials and solutions of polynomial equations. The unit culminates with the fundamental theorem of algebra. Rational numbers extend the arithmetic of integers by allowing division by all numbers except 0. Similarly, rational expressions extend the arithmetic of polynomials by allowing division by all polynomials except the zero polynomial. A central theme of this unit is that the arithmetic operations of rational expressions are governed by the same rules as the arithmetic of rational numbers.
Unit 3 – Triangular Trigonometry	Critical Area 3: Trigonometry of General Triangles and Trigonometric Functions Building on their previous work with functions, and on their work with trigonometric ratios and circles in geometry, students now use the coordinate plane to extend trigonometry to model periodic phenomena. Students develop the Laws of Sines and Cosines in order to find missing measures of general (not necessarily right) triangles. They are able to distinguish whether three given measures (angles or sides) define 0, 1, 2, or infinitely many triangles. This discussion of general triangles opens up the idea of trigonometry applied beyond the right triangle – that is, at least to obtuse angles. Students build on this idea to develop the notion of radian measure for angles and extend the domain of the trigonometric functions to all real numbers. They apply this knowledge to model simple periodic phenomena. Students use trigonometric identities and solve trigonometric equations.
Unit 4 – Graphs of Trigonometric Functions	
Unit 5 – Trigonometric Identities and Equations	

Unit Organization:	Instruction focuses in critical areas:
Unit 6 – Exponential and Logarithmic Functions	Critical Area 4: Exponential and Logarithmic Functions In this unit students synthesize and generalize what they have learned about a variety of function families. They extend their work with exponential functions to include solving exponential equations with logarithms. Students simplify and evaluate exponential expressions with rational and irrational exponents and graph exponential functions. They explore the effects of transformations on graphs of diverse functions, including functions arising in applications, in order to abstract the general principle that transformations on a graph always have the same effect regardless of the type of the underlying functions. They identify appropriate types of functions to model a situation, they adjust parameters to improve the model, and they compare models by analyzing appropriateness and make judgments about the domain over which a model is a good fit.
Unit 7 – Combinatorics and Probability	Critical Area 5: Applications of Probability This unit provides an introduction to some basic concepts of combinatorics and probability. Building on probability concepts that began in the middle grades, students use the languages of set theory to expand their ability to compute and interpret theoretical and experimental probabilities for compound events, attending to mutually exclusive events, independent events, and conditional probability. Students should make use of geometric probability models wherever possible. They use probability to make informed decisions.
Unit 8 – Conics	Critical Area 6: Conic Sections <i>In the Cartesian coordinate system, students use the distance formula to write the equation of a circle when given the radius and the coordinates of its center. Given an equation of a circle, they draw the graph in the coordinate plane, and apply techniques for solving quadratic equations, which relates back to work done in a previous unit. Students use equations to identify key characteristics of each conic section and use the key characteristics to graph circles, ellipses, and hyperbolas.</i>

DEPARTMENT GOALS

Through a planned, sequential curriculum, the Bristol Public schools strive to educate each student according to the standards outlined in the Common Core State Standards for Mathematics in Connecticut including these conceptual categories:

- Number and Quantity
- Algebra
- Functions
- Geometry
- Modeling
- Statistics and Probability

As part of these standards, teacher will support students in developing the following mathematical practices¹:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

¹ The mathematical practices listed are those found in the Common Core State Standards in Connecticut.

PHILOSOPHY OF INSTRUCTION

Based on our department philosophy and goals, math teachers will:

- provide a safe, supportive and respectful classroom environment conducive to learning, where students are encouraged to take risks and share ideas;
- have a deep understanding of the mathematical concepts and skills in the curriculum and strong pedagogical content knowledge;
- use the BOE approved textbook and a variety of resources to have students read about, explore and reinforce curriculum concepts and skills;
- build upon students' prior knowledge and experience, and real-world events, to foster connections and make learning relevant and meaningful;
- provide students with developmentally appropriate opportunities to question, explore, observe, synthesize and draw conclusions based on their mathematics understanding;
- use high-level questions and rich tasks to facilitate classroom discourse, both oral and written, to encourage student-student, student-teacher and teacher-student communication;
- model and have students use manipulatives, tools and technology to actively explore and build understanding of mathematical concepts;
- structure learning experiences that utilize a variety of grouping strategies to encourage collaborative problem solving; and
- differentiate instruction to meet the needs of a variety of learners based on students readiness, interest, and learning style and provide supplemental mathematics intervention or enrichment as needed.

Note: The instructional strategies recommended in our resource document are specific examples of these expectations in practice. They serve as a starting point for planning and implementing instruction that will develop our students as thinkers. Teachers may create new instructional strategies and activities as they continue to grow professionally and as they develop an understanding of each student's unique strengths, weaknesses, and interests.

PHILOSOPHY OF ASSESSMENT

Bases on our department philosophy and goals, math teachers will:

- align assessments with instructions;
- use a variety of formative and summative assessments throughout each unit of instruction;
- design and use assessments that include questions at varied levels of cognitive demand;
- analyze results and plan or modify instruction based on the results;
- provide specific, constructive feedback for students; and
- collaborate with colleagues and use scoring rubrics to evaluate student work as appropriate.

Unit 1 – Functions and Graphs

Major Topics in this Unit:

Relations and Functions
Composition of Functions
Piecewise Functions
Symmetry and Coordinate Graphs
Families of Graphs
Inverse Functions and Relations
Continuity and End Behavior
Critical Points and Extrema
Graphs and Rational Functions

Common Core State Standards in Connecticut

Power Standards are in **BOLD**

A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-REI.10 Understand that the graph of an equation in two variables is the set of all solutions plotted in the coordinate plane, often forming a curve (which could be a line).

A-REI.11 Explain why the x-coordinate of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation $f(x)=g(x)$; find the solutions approximately, e.g., using technology to graph functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

F-IF.1 Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, the $f(x)$ denotes the output f corresponding to the input x . The graph of f is the graph of the equation $y = f(x)$.

F-IF.2 Use function notations, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F-IF.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of quantities, and sketch graphs showing key features given a verbal description of the relationship.

F-IF.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

F-IF.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

F-IF.7a Graph linear and quadratic functions and show intercepts, maxima, and minima.

F-IF.7b Graph square root, cube root, and piece-wise defined functions, including step functions and absolute value functions.

F-IF.7d (+) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

F-BF.1 Write a function that describes a relationship between two quantities.

F-BF.1b Combine standard function types using arithmetic operations.

F-BF.1c Compose functions.

F-BF.3 Identify the effect on the graph of replacing $f(x)$ by $f(x)+k$, $k \cdot f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. *Include recognizing even and odd functions from their graphs and algebraic expression for them.*

F-BF. 4 Find inverse functions.

F-BF.4b (+) Verify by composition that one function is the inverse of the other.

F-BF.4c (+) Read values of an inverse function from a graph or a table, given that the function has an inverse.

F-BF.4d (+) Produce an invertible function from a non-invertible function by restricting the domain.

Unit 1 – Functions and Graphs

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Equations in two or more variables ➤ Relationships between quantities ➤ Equations on coordinate axes ▪ Labels and scales ❖ Graph of equation in two or more variables ➤ Set of all solutions plotted in coordinate plane ➤ Curve (which could be a line) ❖ Solution of the equation $f(x) = g(x)$ ➤ x-coordinate of intersection of functions $y = f(x)$ and $y = g(x)$ ▪ linear ▪ polynomial ▪ rational ▪ absolute value ▪ exponential ▪ logarithmic ❖ Function ➤ One element of domain to exactly one element of range ➤ Domain ▪ x elements ➤ Range ▪ Output ▪ $f(x)$ ➤ Graph ▪ $Y = f(x)$ ❖ Function notation ➤ Input values for domain ➤ In terms of a context ❖ Function ➤ Relationship between two quantities ➤ Key features ▪ Graphs ▪ Tables ▪ Verbal description ❖ Domain of function ➤ Graph	❖ Create (equation) ➤ Represent (relationships) ➤ Graph ❖ Understand (graph) ❖ Explain (why) ➤ Use (technology) ▪ Graph (functions) ▪ Make (tables of value) ▪ Find (successive approximations) ❖ Understand (function) ➤ Assign (element) ➤ Denote (function notation) ❖ Use (function notation) ➤ Evaluate (functions) ➤ Interpret (statements) ❖ Model (functions) ➤ Interpret (key features) ➤ Sketch (graphs) ❖ Relate ➤ Describe

Unit 1 – Functions and Graphs

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ Quantitative relationships ❖ Functions expressed symbolically ➤ By hand in simple cases ➤ Technology for complicated cases ❖ Functions ➤ Linear and Quadratic ▪ Intercepts ▪ Maxima ▪ Minima ➤ Square root ➤ Cube root ➤ Piece-wise defined ▪ Step functions ▪ Absolute value functions ➤ Polynomials ▪ Zeros ▪ Asymptotes ▪ Suitable factorizations ▪ End behavior ➤ Rational ▪ Zeros ▪ Asymptotes ▪ Suitable factorizations ▪ End behavior ❖ Function ➤ Relationship between two quantities ➤ Arithmetic operations ❖ Effect on graph ➤ $f(x) + k$ ➤ $k \cdot f(x)$ ➤ $f(kx)$ ➤ $f(x + k)$ ➤ Even/odd functions ▪ graphs ▪ algebraic expressions ❖ Inverse functions	❖ Graph (key features) ❖ Graph ➤ Show ➤ Identify ❖ Write ➤ Describe ➤ Combine ➤ Compose ❖ Identify ➤ Replace $f(x)$ ➤ Find (k given graph) ➤ Experiment (technology) ▪ Illustrate ▪ Explain ➤ Recognize ❖ Find

Unit 1 – Functions and Graphs

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ Composition ➤ Values ▪ Graph ▪ Table ➤ Domain	➤ Verify ➤ Read ➤ Produce ▪ Restrict

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. A function maps one element of the domain to exactly one element of the range and can be represented by a table, graph, equation or verbal description. 2. Function notation is used to evaluate functions for input values, and represent the graph of $y=f(x)$, or statements in terms of a context. 3. Key features that are used to graph functions include intercepts, maxima, minima, zeros, asymptotes, end behavior, and symmetry. 4. Two or more functions can be combined through addition, subtraction, multiplication, division, or composition to form a new functions. 5. The change to the parent function results in a reflection, translation, or dilation of the graph. 6. Two functions are inverses of each other if their graphs are symmetric to the $y=x$ line, x and y are interchanged in a table or equation, and $f(g(x)) = g(f(x)) = x$.	1. How does a function represent a relationship between two quantities? 2. How is function notation used to describe the relationship between two quantities? 3. How are key features of functions used to model relationship between two quantities? 4. How are arithmetic operations used to combine functions? 5. How is the graph of $f(x)$ effected by replacing $f(x)$ with $f(x)+k$, $k \cdot f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative)? 6. How does an inverse function relate to its original function?

Unit 1 – Functions and Graphs Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-IF.1	EQ.1	Determine whether a given relation is a function.	Ask students to compare a function and relation. Utilize various strategies, including: ▪ mapping ▪ vertical line test, and ▪ solve for “y”	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
F-IF.1	EQ.1	Identify the domain and range of a relation or function.	Have students find the domain and range given an equation, a graph, and a table. Utilize the graphing calculator. Include examples where there are restrictions on the domain. (<i>Use more complex quadratics and square roots in the denominator for ACC.</i>)	Have students write an example of a relation that is a function and an example of one that is not. Then have them write a sentence or two explaining the difference between the two examples.

Unit 1 – Functions and Graphs Learning Plan				
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F-BF.1b	EQ.4	Perform operations with functions.	Provide addition, subtraction, multiplication, and division examples Emphasize domain restrictions when dividing. <i>Include examples that require factoring.</i>	
F-BF.1c	EQ.4	Find the composition of functions.	Emphasize notation and vocabulary $f(g(x)) = (f \circ g)(x)$ is found by substituting $g(x)$ for x in $f(x)$. Emphasize the second function is the one substituted first. <i>Discuss the domain of a composite function. Include restrictions on the domain.</i>	
A-REI.10 F.IF.4 F.IF.5	EQ.3	Identify and graph piecewise functions including greatest integer, step, and absolute value functions.	Connect to the composition of functions. <i>Include quadratic functions for ACC.</i> When graphing a greatest integer functions, have students make a table first. Note the difference between open and closed circles. Remind students that absolute value functions have a “V” shape.	

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F.IF.4	EQ.3	Use algebraic tests to determine if the graph of a relation is symmetrical.	Provide examples of point symmetry, line of symmetry, and symmetry with respect to the origin, x-axis, and y-axis. Emphasize if symmetry exists with respect to the origin, a point (x,y) and (-x,-y) will be on the graph Emphasize if symmetry exists with respect to the y-axis, a point (x,y) and (-x,y) will be on the graph Use numerical examples to see the difference between $f(-x)$ and $-f(x)$. <i>Then verify algebraically.</i> Set up a chart when testing possible lines of symmetry.	Write a paragraph discussing when a relation is symmetric with respect to the x-axis, the y-axis, the line $y=x$, the line $y=x$, the line $y = -x$, or none of these.
F.IF.4 F-BF.3	EQ.3	Classify functions as even or odd.	Emphasize even functions are symmetric with respect to the y-axis. Odd functions are symmetric with respect to the x-axis. Show students if you rotate the graph 180 degrees it looks like the original. Test numerical values <i>then verify algebraically.</i>	<i>Suppose $f(x)$ is an even function and $g(x)$ is an odd function. Is $h(x) = f(x) \cdot g(x)$ an even function, an odd function or neither? Justify your answer.</i>

Unit 1 – Functions and Graphs Learning Plan				
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F-BF.3	EQ.5	Identify transformations of parent graphs and parent functions.	Recall the families of functions (constant, linear, polynomial, square root, absolute value, greatest integer, rational)	
F-BF.3	EQ.5	Sketch graphs of related functions.	Show various transformations, including: - vertical translation - horizontal translation - reflection over the x-axis - reflection over the y-axis - stretch and compress vertically and horizontally	
A.CED.2	EQ.5	Write the equation of a function given the graph.	Encourage students to start with the parent function when writing an equation	
A-REI.10 F-IF.4 F-IF.5 F-IF.7 F-IF.7a F-IF.7b F-IF.7c	EQ.3	Graph polynomial, absolute value, and <i>radical inequalities</i> in two variables.	Remind students when they are graphing inequalities that they are finding ALL ordered pairs that satisfy the inequality. Review solid versus dotted boundary lines. Use (0,0) as a test point whenever it is not on the boundary line. Utilize the graphing calculator.	Ask students to explain how to graph an inequality. Have them describe how to determine where the graph should be shaded.

Unit 1 – Functions and Graphs Learning Plan				
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A-REI.11	EQ.3	Solve absolute value inequalities.	Remind students that when solving an inequality, the sign only changes when multiplying or dividing by a negative number. There are two cases that must be solved when solving absolute value inequalities: $<$ or $\leq$ translates to an “and” statement $>$ or $\geq$ translates to an “or” statement	
F-BF.4 F-BF.4c F-BF.4d	EQ.6	Determine the inverse of relations and functions.	Emphasize inverse notation $f^{-1}(x)$ Remind students that the inverse function is symmetric about the $y=x$ line.	
A-CED.2 A-REI.10 F-IF.4 F-IF.5 F-IF.7 F-BF.4c	EQ.6	Graph functions and their inverses.	Utilize the horizontal line test to determine whether the inverse is a function Use different colored pencils to differentiate between the original graph and its inverse.	
F-IF.1	EQ.6	Determine whether two	Verify inverse functions by finding	

Unit 1 – Functions and Graphs Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-BF.4c		functions are inverses of each other	both composite functions, $f(g(x))$ and $g(f(x))$ Show students that the graph of the inverse is a reflection over the line $y=x$.	
F-IF.4	EQ.3	Determine whether a function is continuous or discontinuous.	Stress that for a function to be continuous it must satisfy ALL three conditions. If all three conditions are not met, then the function is discontinuous. Provide examples of functions that fail only one condition but pass the others. Discuss what an open circle and closed circle mean.	<i>Have students write an explanation why the square root function is undefined under certain intervals.</i>
F-IF.4	EQ.3	Identify the end behavior of functions.	Stress that the end behavior of the polynomials depends on the end behavior of the leading term when terms are listed in order from the highest power of x . Utilize the graphing calculator.	Have students write an explanation of how to determine the end behavior of a function.
F-IF.4	EQ.3	Determine whether a function	Have students sketch a graph and	

Unit 1 – Functions and Graphs Learning Plan				
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		is increasing or decreasing on an interval.	divide the graph into intervals, labeling each interval as increasing and decreasing. Review basic shapes of quadratic, cubic, absolute value, and rational functions.	
F-IF.4	EQ.3	Find the extrema of a function.	Point out that a graph can have more than one relative minimum or maximum. When using the graphing calculator, emphasize that students must change the WINDOW to be able to see all of the shape. Use a table of values, the TRACE function, or CALC min or CALC max to approximate maxima or minima of a function.	<i>Given the graph of $y=\sin\alpha$, describe the extrema of the function.</i>
A-REI.10 F-IF.7 F-IF.7d	EQ.3	Graph rational functions.	Recall that $f(x) = 1/x$ is the parent graph for rational functions.	
F-IF.4	EQ.3	Determine vertical, horizontal,	Examine the quotient of the leading	Ask students to explain how to predict

Unit 1 – Functions and Graphs Learning Plan				
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F-IF.7d		and <i>slant asymptotes</i> .	terms of the numerator and denominator in order to find horizontal asymptotes. Find vertical asymptotes by setting the expression in the denominator = 0 and solving for x. <i>Show how long division can be used to determine the slant asymptote and to determine the horizontal asymptote when the degree of the numerator and denominator are equal.</i>	the equations of the asymptotes.

Unit 1 – Functions and Graphs Common Learning Experiences and Assessments	
• http://www.illustrativemathematics.org/illustrations/635 - Domains • http://www.illustrativemathematics.org/illustrations/671 - Flu on campus (composition of functions) • http://www.illustrativemathematics.org/illustrations/742 - Transforming the graph of a function	

Unit 2 – Polynomial and Rational Functions

Major Topics in this Unit:

Operations with Complex Numbers
 Factoring
 Polynomial Functions
 Quadratic Equations
 Remainder and Factor Theorems
 Rational Root Theorem
 Locating Zeros of Polynomial Functions
 Rational Equations
 Radical Equations
 Modeling Real World Data with Polynomial Functions

Common Core State Standards in Connecticut

Power Standards are in **BOLD**

N-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2 Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

N-CN.1 Know there is a complex number i such that $i^2 = -1$, and every complex number has the form $a + bi$ with a and b real.

N-CN.2 Use the relation $i^2 = -1$ and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

N-CN.3 (+) Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers.

N-CN.7 Solve quadratic equations with real coefficients that have complex solutions.

N-CN.8 (+) Extend polynomial identities to the complex numbers.

N-CN.9 (+) Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

A-SSE.1 Interpret expressions that represent a quantity in terms of its context.

A-SSE.1a Interpret parts of an expression, such as terms, factors, and coefficients.

A-SSE.2 Use structure of an expression to identify ways to rewrite it.

A-SSE.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3a Factor a quadratic expression to reveal zeros of the function it defines.

A-SSE.3b Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.

A-APR.2 Know and apply the Remainder Theorem: For a polynomial $p(x)$ and a number a , the remainder on division by $x - a$ is $p(a)$, so $p(a) = 0$ if and only if $(x - a)$ is a factor of $p(x)$.

Unit 2 – Polynomial and Rational Functions

A-APR.3 Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

A-CED.1 Create equations and inequalities in one variable and use them to solve problems.

A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-REI.1 Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

A-REI.2 Solve simple rational and radical equations in one variable, and give examples show how extraneous solutions may arise.

A-REI.4 Solve quadratic equations in one variable.

A-REI.4a Use the method of completing the square to transform any quadratic equation in x into an equation of the form $(x - p)^2 = q$ that has the same solutions. Derive the quadratic formula from this form.

A-REI.4b Solve quadratic equations by inspection (e.g., for $x^2 = 49$), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as $a \pm bi$ for real number a and b .

A-REI.10 Understand that the graph of an equation in two variables is the set of all solutions plotted in the coordinate plane, often forming a curve (which could be a line).

A-REI.11 Explain why the x -coordinate of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation $f(x)=g(x)$; find the solutions approximately, e.g., using technology to graph functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

F-IF.2 Use function notations, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F-IF.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of quantities, and sketch graphs showing key features given a verbal description of the relationship.

F-IF.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

F-IF.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

F-IF.7a Graph linear and quadratic functions and show intercepts, maxima, and minima.

Unit 2 – Polynomial and Rational Functions

F-IF.7c Graph polynomial functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

F-IF.8 Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

F-IF.8a Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context.

F-BF.4a Solve an equation of the form $f(x)=c$ for a simple function f that has an inverse and write an expression for the inverse.

Unit 2 – Polynomial and Rational Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Units ➤ Problems ➤ Solution of multi-step problems ➤ Formulas ➤ Graphs ▪ Scale ▪ Origin ➤ Data Displays ❖ Descriptive modeling ❖ Level of accuracy ➤ Limitations on measurement ❖ Complex number i ➤ $i^2 = -1$ ➤ $a + bi$, a and b real ❖ Properties ➤ $i^2 = -1$ ➤ Commutative ➤ Associative ➤ Distributive ❖ Quadratic equations with real coefficients ➤ Complex solutions ❖ Polynomial Identities ➤ Complex numbers ❖ Fundamental Theorem of Algebra ➤ True for quadratic polynomials ❖ Expression ➤ Quantity in terms of its context ➤ Parts of an expression ▪ Terms ▪ Factors ▪ Coefficients ❖ Structure of an expression ❖ Equivalent forms of an expression ➤ Properties of the quantity	❖ Use (units) ➤ Understand ➤ Guide ➤ Choose ➤ Interpret ❖ Define (appropriate quantities) ❖ Report (quantities) ❖ Know ❖ Use (relations) ➤ Add ➤ Subtract ➤ Multiply ❖ Solve ❖ Extend ❖ Know ➤ Show ❖ Interpret ❖ Use (structure) ➤ Rewrite ❖ Choose ➤ Produce

Unit 2 – Polynomial and Rational Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ Quadratic expression ▪ Zeros of the functions ▪ Maximum value ▪ Minimum value ❖ The Remainder Theorem ➤ $(x-a)$ factor of $p(x)$ if and only if $p(a) = 0$ ❖ Zeros of polynomials ➤ Suitable factorizations ➤ Rough graph of function ❖ Equations and inequalities in one variable ➤ Problems ❖ Equations in two or more variables ➤ Relationships between quantities ➤ Graph ▪ Coordinates axes ▪ Labels ▪ Scales ❖ Steps in solving simple equations ➤ Equality of numbers ➤ Original equation with solution ➤ Viable argument ➤ Solution Method ❖ Equations in one variable ➤ Simple rational ➤ Radical ▪ Extraneous solutions ➤ Quadratic ▪ Appropriate method in initial form • Completing the square $(x - p)^2 = q$ • Quadratic Formula ◦ Complex solutions: $a \pm bi$ • Inspection • Square roots • Factoring ▪ In terms of a context	➤ Reveal ➤ Explain ➤ Represent ➤ Factor ➤ Complete (the square) ❖ Know ➤ Apply ❖ Identify ➤ Construct ❖ Create ➤ Solve ❖ Create ❖ Explain ➤ Construct ➤ Justify ❖ Solve ➤ Show ➤ Transform ➤ Derive ➤ Choose ➤ Interpret

Unit 2 – Polynomial and Rational Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
• Zeros • Extreme values • Symmetry of the graph ❖ Graph of equation in two variables ➢ Set of all solutions ➢ Coordinate planeCurve (which could be a line) ❖ Solution of the equation $f(x) = g(x)$ ➢ X-coordinate of intersection of functions $y = f(x)$ and $y = g(x)$ ▪ linear ▪ polynomial ▪ rational ▪ absolute value ▪ exponential ▪ logarithmic ❖ Function notation ➢ Input values for domain ➢ In terms of a context ❖ Function ➢ Relationship between two quantities ➢ Key features ▪ Graphs ▪ Tables ▪ Verbal description ❖ Domain of function ➢ graph ➢ Quantitative relationships ❖ Functions expressed symbolically ➢ By hand in simple cases ➢ Technology for complicated cases ❖ Functions ➢ Linear and Quadratic ▪ Intercepts ▪ Maxima ▪ Minima ➢ Polynomials ▪ Zeros ▪ Asymptotes	❖ Understand ➢ Plot ❖ Explain (why) ➢ Use (technology) ▪ Graph (functions) ▪ Make (tables of value) ▪ Find (successive approximations) ❖ Use (function notation) ➢ Evaluate (functions) ➢ Interpret (statements) ❖ Model (functions) ➢ Interpret (key features) ➢ Sketch (graphs) ❖ Relate ➢ Describe ❖ Graph (key features) ❖ Graph ➢ Show ➢ Identify

Unit 2 – Polynomial and Rational Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
▪ Suitable factorizations ▪ End behavior ➤ Rational ▪ Zeros ▪ Asymptotes ▪ Suitable factorizations ▪ End behavior ❖ Equation of the form $f(x)=c$ ➤ Expression for inverse	❖ Solve ➤ Write

Unit 2 – Polynomial and Rational Functions

Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Using the relation $i^2 = -1$, you can add, subtract, multiply and divide complex numbers that can be written in a $+ bi$ with a and b real. 2. You can factor a quadratic expression to reveal the zeros of a function and construct its graph. You can complete the square to reveal the maximum or minimum value of a function. 3. If a polynomial $p(x)$ is divided by $x - a$, $(x - a)$ is a factor of $p(x)$ if and only if $p(a) = 0$, by the Factor Theorem. 4. Quadratic equations can be solved by inspection, completing the square, taking square roots, the quadratic formula, and factoring. 5. You can solve simple rational and radical equations using inverse operations based on properties of equality following from the previous step, assuming the original equation has a solution. Extraneous solutions may arise from squaring both sides of the equation. 6. Key features of polynomials can be identified from tables, graphs, equations, or verbal descriptions.	1. How can you use the relation $i^2 = -1$ to simplify complex numbers? 2. How can you produce an equivalent form of an expression to reveal and explain properties represented by the expression? 3. How does the Remainder Theorem apply to the division of polynomials? 4. How can you solve quadratic equations? 5. How can you solve simple rational and radical equations? 6. How can a polynomial function model the relationship between two quantities?

Unit 2 – Polynomial and Rational Functions Learning Plan				
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N-CN.1 N-CN.2 N-CN.3	EQ.1	Add, subtract, multiply, and divide complex numbers	Show that the sum, difference, product, or quotient of two complex numbers is also a complex number. Complex numbers should be expressed in the form $a + bi$. Review multiplying binomials Discuss patterns with powers of i.	Pre-Assessment Do-Now's Formative Assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
A-SSE.1a A-SSE.2 A-SSE.3a	EQ.2	Factor polynomials.	Distinguish between GCF, Difference of Two Squares, Trinomials, Grouping, and Quartic in Quadratic Form	
N-CN.9	EQ.2	Determine the roots of polynomial equations.	Review how to find the degree of a polynomial and its leading coefficient Discuss the Fundamental Theorem of Algebra. Include imaginary roots. Use imaginary roots to write equations	
A-SSE.1 F-IF.2	EQ.3	Evaluate a polynomial function to determine if the value is a zero of the function.	Demonstrate evaluating a polynomial using both substitution and synthetic Division. Include imaginary roots.	

Unit 2 – Polynomial and Rational Functions Learning Plan				
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N-CN.8 A-APR.3 F-IF.4	EQ.2	Distinguish between the graphs of various polynomial functions.	Provide a graphic organizer which includes degrees, names, and general shapes of various polynomials Provide non-examples of polynomials Emphasize how the number of maximum and minimum values of a polynomial function is one less than the degree of the polynomial functions Construct a sign analysis chart Connect even and odd degree, to number of roots Distinguish between real and imaginary roots, double roots and triple roots based on the graph	
F-IF.7 F-IF.7b F-IF.7c	EQ.2	Graph a sketch of a polynomial function.	Point out that the real zeros are shown as x-intercepts on the graph. <i>Include examples with double, triple, and imaginary roots.</i>	

Unit 2 – Polynomial and Rational Functions Learning Plan				
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N-CN.7 A-SSE.3 A-REI.4 A-REI.4a A-REI.4b A-REI.11 F-IF.8 F-IF.8a F-BF.4a	EQ.4	Solve quadratic equations.	Focus on choosing the most efficient method of solving. Include factoring, square root, and completing the square.	
A-REI.4b	EQ.4	Use the discriminant to describe the roots of quadratic equations.	Relate number of x-intercepts to complex solutions to solving by graphing and the quadratic formula.	Have students explain what the discriminant of a quadratic equation is and what its value reveals. Show that if a and c have different signs, then $ax^2 + bx + c = 0$, has two real roots.

Unit 2 – Polynomial and Rational Functions Learning Plan				
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A-SSE.1a	EQ.3	Find the factors of a polynomial function.	Introduce synthetic division as a method to find the factors Remind students to insert a zero in a synthetic division problem if any powers of x in the dividend have coefficients of zero. Look at the graph to find zeros. Compare the two methods used to determine whether an expression is a factor (long division and synthetic division) Utilize the Remainder and Factor Theorems.	
A-SSE.1a	EQ.3	Identify all possible rational roots of a polynomial equation.	Utilize the Rational Root Theorem to find all the possible roots. Demonstrate how to narrow down the possibilities using a graphing calculator. Show students how to check a zero using synthetic division. Make sure students relate the numbers of solutions to the degree of the polynomial so imaginary roots are not forgotten.	

Unit 2 – Polynomial and Rational Functions Learning Plan				
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A-REI.11	EQ.3	Approximate the real zeros of a polynomial function.	Locate zeros in a table or graph as the values of the functions go from positive to negative or negative to positive. Remind students that imaginary zeros cannot be approximated from a table or graph. Stress the word <i>approximate</i>. Utilize the graphing calculator.	
A-REI.1 A-REI.2 A-REI.11 F-BF.4a	EQ.5	Solve rational equations and Inequalities.	Look to factor polynomials to simplify the problem. Write down any impossible solutions before solving a rational equation. Stress the denominator can never be zero.	
A-REI.1 A-REI.2 A-REI.11 F-BF.4a	EQ.5	Solve radical equations.	<i>Remind students of the possibility of extraneous solutions when squaring both sides.</i> Remind students that odd roots can be negative, while even roots cannot be negative.	Have students explain the major steps involved in solving a radical equation that contains only one radical. <i>Then, have them compare this to the steps necessary if two radicals are present.</i>

Unit 2 – Polynomial and Rational Functions Learning Plan				
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N-Q.1 N-Q.2 N-Q.3 A-SSE.1 A-SSE.3 A-CED.1 A-CED.2	EQ.6	Write polynomial functions to model real-world data.	Prompt students to first identify the general shape of the graph based on patterns found in the data Utilize graphing calculator and various types of regression Use 9:ZOOMSTAT to fit the window for the data.	Provide students with a set of data for which there appears to be a polynomial model. Ask them to find the polynomial that best fits the data and explain their response. Make predictions based on the model.
N-Q.1 N-Q.2 N-Q.3 A-SSE.1 A-SSE.3 A-CED.1 A-CED.2 F-IF.5	EQ.6	Use polynomial functions to interpret real-world data.	Utilize real-world data from a variety of sources to model various degrees of polynomials Have students write their own data sets from a given type of polynomial	
N-Q.1 N-Q.2 N-Q.3 A-SSE.1 A-SSE.3 A-CED.1 A-CED.2	EQ.6	Use polynomial functions to predict.	Utilize graphing calculator.	<i>Is it always appropriate to use a polynomial model for a scatter plot in order to predict beyond the range of the data given? give an example to support</i>

Unit 2 – Polynomial and Rational Functions

Common Learning Experiences and Assessments

- <http://www.illustrativemathematics.org/illustrations/617> - Computations with Complex Numbers (ACC only)
- <http://www.illustrativemathematics.org/illustrations/1690> - Completing the square
- <http://map.mathshell.org/materials/lessons.php?taskid=436&subpage=concept> – Representing polynomials
- <http://map.mathshell.org/materials/download.php?fileid=834> - Short Tasks: Arithmetic with Polynomials and Rational Expressions 1
- <http://illuminations.nctm.org/Lesson.aspx?id=1091> – Building connections (ACA only)
- <http://www.illustrativemathematics.org/illustrations/592> - The missing coefficient (ACC only)
- <http://map.mathshell.org/materials/tasks.php?taskid=265&subpage=apprentice> – Cubic graph
- <http://www.illustrativemathematics.org/illustrations/1694> - Graphing Rational Functions
- <http://illuminations.nctm.org/Lesson.aspx?id=1968> – Light it up (Rational Functions)
- <http://www.illustrativemathematics.org/illustrations/391> - Solve radical equations

Unit 3 – Triangular Trigonometry

Major Topics in this Unit:

Angles and Degree Measure
 Trigonometric Ratios in Right Triangles
 Trigonometric Functions on the Unit Circle
 Applying Trigonometric Functions
 Solving Right Triangles

Common Core State Standards in Connecticut

Power Standards are in **BOLD**

A-CED.1 Create equations and inequalities in one variable and use them to solve problems.

A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

F-IF.2 Use function notations, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F-BF.4 Find inverse functions

F-TF.2 Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.

F-TF.3 (+) Use special triangles to determine geometrically the values of sine, cosine, tangent for $\frac{\pi}{3}$, $\frac{\pi}{4}$, and $\frac{\pi}{6}$, and use the unit circle to express the

values of sine, cosine, and tangent for $\pi - x$, $\pi + x$, and $2\pi - x$ in terms of their values for x , where x is any real number.

F-TF.7 (+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of a context.

G-SRT.6 Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G-SRT.8 Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

G-SRT.9 (+) Derive the formula $A = \frac{1}{2} ab \sin(C)$ for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side.

G-SRT.10 (+) Prove the Law of Sines and Cosines and use them to solve problems.

G-SRT.11 (+) Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

Unit 3 – Triangular Trigonometry Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Equations and inequalities in one variable ➤ Problems ❖ Equations in two or more variables ➤ Relationships between quantities ➤ Graph ▪ Coordinates axes ▪ Labels ▪ Scales ❖ Function notation ➤ Input values for domain ➤ In terms of a context ❖ Inverse functions ❖ Unit circle ➤ Trigonometric functions ➤ Radian measures ▪ Angles traversed counterclockwise ❖ Values using special triangles ➤ For sine, cosine, and tangent for $\frac{\pi}{3}$, $\frac{\pi}{4}$, and $\frac{\pi}{6}$ ➤ For sine, cosine and tangent for $\pi - x$, $\pi + x$, $2\pi - x$ ❖ Trigonometric equations ➤ Inverse functions ➤ Modeling contexts ➤ Solutions ▪ Technology ▪ In terms of a context ❖ Side ratios of right triangles ➤ Properties of angles in a triangle ▪ Similarity ➤ Trigonometric ratios for acute angles ❖ Right Triangles ➤ Trigonometric ratios ➤ Pythagorean Theorem ➤ Applied problems	❖ Create ➤ Solve ❖ Create ❖ Use (function notation) ➤ Evaluate (functions) ➤ Interpret (statements) ❖ Find ❖ Explain ➤ Extend ➤ Interpret ❖ Determine ➤ Express (values) ❖ Solve ➤ Use ➤ Evaluate ➤ Interpret ❖ Understand ➤ Define ❖ Solve

Unit 3 – Triangular Trigonometry Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Formula for area of a triangle ➤ $A = 1/2 ab \sin C$ ▪ Auxiliary line from vertex perpendicular to opposite side. ❖ Law of Sines and Cosines ➤ Unknown measurements ▪ Right triangles ▪ Non-right triangles • Surveying problems • Resultant forces	❖ Derive ➤ Draw ❖ Prove ➤ Solve ➤ Understand ➤ Apply

Unit 3 – Triangular Trigonometry Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Positive angles are formed by moving counterclockwise around the unit circle and are measured in radians and degrees. 2. The $\sin x = \text{opposite side/hypotenuse}$. The $\cos x = \text{adjacent side/hypotenuse}$. The $\tan x = \text{opposite side/adjacent side}$. The $\csc x$, the $\sec x$, and the $\cot x$ are found by taking the reciprocal ratio of their respective function. 3. You can solve for the sides of a right triangle using trigonometric ratios and the Pythagorean Theorem. You can solve for the angles using inverse trigonometric functions. 4. The Law of Sines and Law of Cosines can be used to find unknown measures in right and non-right triangles.	1. How are angles measured on the unit circle? 2. How do you calculate trigonometric ratios for acute angles in right triangles? 3. How can you solve right triangle using trigonometric ratios? 4. How can you solve non-right triangles?

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.2	EQ.1	Convert decimal degree measures to degrees, minutes, and seconds and vice versa.	Introduce angle vocabulary, including vertex, terminal side, initial side, and standard position	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
F-TF.2	EQ.1	Find the number of degrees in a given number of rotations.	Emphasize counterclockwise rotation is a positive angle and clockwise rotation is a negative angle. <i>DMS on the [Angle] menu allows students to convert decimal degree values to degrees, minutes, and seconds.</i>	
F-TF.2	EQ.1	Identify angles that are coterminal with a given angle.	Remind students that a quick way to verify coterminal angles is to make sure their difference is an integer multiple of 360°	

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			Emphasize that coterminal angles are in standard position with the same terminal side.	
F-TF.2	EQ.1	Find the measure of the reference angle for a given angle.	Develop reference angle rules Emphasize the reference angle is always an acute angle formed on the x-axis.	Have students explain how to find the reference angle of any angle.
F-TF.3 G-SRT.6	EQ.2	Find the values of trigonometric ratios for acute angles of right triangles.	Discuss vocabulary, including Hypotenuse, legs, side opposite, and side adjacent Define the right triangle trigonometric ratios using words, symbols, definition and diagrams Utilize Pythagorean theorem Review rationalizing denominators. Utilize the mnemonic device – SOH - CAH – TOA Express answers in both simplest radical form and decimal form Make sure students set their calculators	Give students a right triangle with two sides given. Ask students to explain how to find the values of the six trigonometric ratios.

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
G-SRT.8	EQ.3	Use trigonometry to find the measures of the sides of right triangles.	to degree mode. Provide examples of the most commonly used functions (sine, cosine and tangent) Remind students that the corresponding lowercase letter is used to represent the measure of the side opposite the angle. Discuss how surveyors use angles of elevation and depression. Have students draw diagrams from the information given in applications and what ratios the given information represents.	Have students write an application problem that requires trigonometric ratios to solve. Students should write out complete solutions for their own problems, including explanations for each step.
F-TF.2	EQ.1 EQ.2	Find the values of the six trigonometric functions using the unit circle.	Define unit circle. Remind students that sine and cosine always range between 1 and -1 while the others do not. Utilize the Pythagorean $\sin \theta = y$ $\cos \theta = x$ - The other four trigonometric functions Demonstrate how to use reference angles to find the point of the unit circle Emphasize how the sign of the	

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			trigonometric function depends which quadrant the point is in Utilize a graphic organizer for sign analysis of trigonometric functions	
G-SRT.8	EQ.1 EQ.2	Find the values of the six trigonometric functions of an angle in standard position given a point on its terminal side.	Remind students that a point on the terminal side of an angle defines a right triangle when a perpendicular is drawn to an axis Introduce the trigonometric ratios based on a circle Prompt students to memorize the six trigonometric functions for an angle in standard position Utilize $r = \sqrt{x^2 + y^2}$ to find an unknown radius	
F-IF.2	EQ.2	Evaluate the sine, cosine, tangent, secant, cosecant and cotangent of an angle determined by any point a circle.	Explain how to use the Pythagorean theorem to determine unknown values in trigonometric ratios	
F-IF.2	EQ.2	Evaluate the remaining trigonometric ratios given the value of any one trigonometric ratio.	Compare and contrast the values of the functions in different quadrants	

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			Lead students to recognize that all trigonometric functions are ratios and can be formulated using x , y and r .	
F-IF.2 F-BF.4	EQ.3	Evaluate inverse trigonometric functions.	Introduce inverse notation, including $x = \sin^{-1} y$ or $x = \arcsin y$ Emphasize that the inverse sin is a relation, not a function. Review that the inverse function is found by interchanging the coordinates of ordered pairs of the function.	
G-SRT.8	EQ.3	Find missing angles of a right triangle.	Stress that inverse functions are used to find the angles where trig functions are used to find the ratios of sides. Utilize calculators to find the values of inverse trigonometric relations Emphasize when using the calculator, the ratio needs to be in parentheses to evaluate the inverse.	
A-CED.1 G-SRT.8	EQ.3	Solve a right triangle.	Explain to students that solving a triangle means to find all the measures of the sides and the angles. Pythagorean Theorem is the easiest way to find the third side of a right triangle when the other two sides are given its sides and angles	Have students explain the process of solving a right triangle when either two sides are given, or one side and an angle are given.

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			Create a chart of the most frequently used angles and their corresponding values of the three basic functions (sine, cosine, and tangent)	
G-SRT.11 G-SRT.10	EQ.4	Use the Law of Sines to find unknown parts of a triangle.	Emphasize how Law of Sines uses proportional thinking in AAS, ASA, or SSA triangles For SSA, explore the ambiguous case Provide examples where there is one, two and no solutions Remind students if the given non-included angle is acute, check for multiple solutions. <i>Have students derive the Law of Sines from a given figure.</i>	
G-SRT.10 G-SRT.11	EQ.4	Use the Law of Cosines to find unknown parts of a triangle.	Emphasize Law of Cosines is used in SAS and SSS triangles Encourage students to memorize one formula and utilize it to derive the other two formulas	
G-SRT.9	EQ.4	Find the area of a triangle	Make connections between $A = \frac{1}{2}bh$ and $K = \frac{1}{2}bc \sin A$	

Unit 3 – Triangular Trigonometry Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			Emphasize formula can be used when two sides and the included angle is known Utilize Hero's Formula if three sides are given	
G-SRT.8	EQ.2 EQ.4	Determine the best method of finding the missing part of a triangle.	Use a graphic organizer to help students summarize various methods of finding missing parts.	
A-CED.1 F-TF.7 G-SRT.8	EQ.2 EQ.4	Use trigonometry to solve real world problems.	Provide examples of real world applications including • Navigation problems • Angles of depression • Angles of elevation • Survey problems • Heights of buildings	

Unit 3 – Triangular Trigonometry

Common Learning Experiences and Assessments

- <http://www.illustrativemathematics.org/illustrations/1692> - Trigonometric functions for arbitrary angles
- <http://illuminations.nctm.org/Lesson.aspx?id=2433> - Law of Sines
- <http://illuminations.nctm.org/Lesson.aspx?id=2441> – Law of Cosines (ACC only)
- https://www.georgiastandards.org/Common-Core/Common%20Core%20Frameworks/CCGPS_Math_9-12_Pre-Calculus_Unit2SE.pdf
- Right Triangle trigonometry
- https://www.georgiastandards.org/Common-Core/Common%20Core%20Frameworks/CCGPS_Math_9-12_Pre-Calculus_Unit3SE.pdf
- Trigonometry of general triangles

Unit 4 – Graphs of Trigonometric Functions

Major Topics in this Unit:

Angles and Radian Measure
 Graphing Sine and Cosine Functions
 Amplitude and Period of Sine and Cosine Functions
 Translations of Sine and Cosine Functions
 Modeling Real-World Data with Sinusoidal Functions
Graph Other Trigonometric Functions
 Trigonometric Inverses and Their Graphs

Common Core State Standards in Connecticut

Power Standards are in **BOLD**

N-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2 Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A-SSE.1 Interpret expressions that represent a quantity in terms of its context.

A-SSE.1a Interpret parts of an expression, such as terms, factors, and coefficients.

A-SSE.1b Interpret complicated expressions by viewing one or more of their parts as a single entity.

A-SSE.2 Use the structure of an expression to identify ways to rewrite it.

A-CED.1 Create equations and inequalities in one variable and use them to solve problems.

A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-REI.10 Understand that the graph of an equation in two variables is the set of all solutions plotted in the coordinate plane, often forming a curve (which could be a line).

F-IF.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of quantities, and sketch graphs showing key features given a verbal description of the relationship.

F-IF.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

F-IF.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

F-IF.7e Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

F-BF.3 Identify the effect on the graph of replacing $f(x)$ by $f(x)+k$, $k \cdot f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology.

Unit 4 – Graphs of Trigonometric Functions

F-BF.4 Find inverse functions.

F-BF.4d (+) Produce an invertible function from a non-invertible function by restricting the domain.

F-TF.1 Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle.

F-TF.5 Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.

F-TF.6 Understand that restricting a trigonometric function to a domain on which it is always increasing or decreasing allows its inverse to be constructed.

G-C.5 Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.

Unit 4 – Graphs of Trigonometric Functions Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Units ➤ Problems ➤ Solution of multi-step problems ➤ Formulas ➤ Graphs ▪ Scale ▪ Origin ➤ Data Displays ❖ Descriptive modeling ❖ Level of accuracy ➤ Limitations on measurement ❖ Expressions that represent a quantity ➤ In terms of its context ➤ Parts of an expression ▪ Terms ▪ Factors ▪ Coefficients ➤ Complicated expressions ▪ One or more of their parts as single entity ❖ Structure of an expression ❖ Equations and inequalities ➤ In one variable ▪ Relationships between quantities	❖ Use (units) ➤ Understand ➤ Guide ➤ Choose ➤ Interpret ❖ Define (appropriate quantities) ❖ Report (quantities) ❖ Interpret ➤ View ❖ Use ➤ Identify ➤ Rewrite ❖ Create

Unit 4 – Graphs of Trigonometric Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
▪ Problems ➤ Equations in two or more variables ▪ Relationship between quantities ▪ Graph • Coordinate axes • Labels and scales ❖ Graph of equation in two variables ➤ Set of all solutions plotted in coordinate plane ➤ Curve (which could be a line) ❖ Relationship between two quantities ➤ Key features in terms of quantities ▪ Tables ▪ Graphs ▪ Verbal descriptions ❖ Domain of functions/graph/quantitative relationship ❖ Functions expressed symbolically ➤ Key Features ➤ By hand in simple cases ➤ Technology for complicated cases ❖ Functions ➤ Exponential and logarithmic ▪ Intercepts ▪ End behavior ➤ Trigonometric ▪ Period ▪ Midline ▪ Amplitude ❖ Effect on graph ➤ $f(x) + k$ ➤ $k \cdot f(x)$ ➤ $f(kx)$ ➤ $f(x + k)$ ➤ Even/odd functions ▪ graphs ▪ algebraic expressions ❖ Inverse functions ➤ Composition	❖ Understand ❖ Model ➤ Interpret ➤ Sketch ❖ Relate ❖ Graph ➤ Show ❖ Graph ➤ Show ❖ Identify ➤ Replace $f(x)$ ➤ Find (k given graph) ➤ Experiment (technology) ▪ Illustrate ▪ Explain ➤ Recognize ❖ Find ➤ Verify

Unit 4 – Graphs of Trigonometric Functions Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ Values ▪ Graph ▪ Table ➤ Domain ❖ Radian measure of an angle ➤ Length of the arc on the unit circle subtended by angle ❖ Trigonometric functions ➤ Periodic phenomena ▪ Amplitude ▪ Frequency ▪ Midline ❖ Restricted domain to increasing or decreasing ➤ Inverse ❖ Length of arc intercepted by angle proportional to radius ➤ Radian measure of angle as constant of proportionality ➤ Formula for area of a sector	➤ Read ➤ Produce ❖ Understand ❖ Choose ➤ Model ❖ Understand ➤ Construct ❖ Derive ➤ Define

Unit 4 – Graphs of Trigonometric Functions Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Radian measure is the length of the arc subtended by the angle. The length of the arc intercepted by an angle is proportional to the radius and the radian measure of the angle is the constant of proportionality. 2. Sine and cosine functions can be used to model periodic phenomena with specified amplitude, frequency, and midline. The graphs of tangent, cotangent, secant, and cosecant also have asymptotes. 3. Restricting a trigonometric function to a domain on that is always increasing or decreasing allows the inverse to be constructed.	1. How is radian measure defined in terms of the unit circle? 2. How can trigonometric functions be used to model periodic phenomena? 3. How can you produce an invertible function from a non-invertible function?

Unit 4 – Graphs of Trigonometric Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.1 G-C.5	EQ.1	Convert from radian measure to degree measure and vice versa.	Provide conversion formulas for angle measurement Use string activity to determine an angle with measure of one radian Utilize circumference formula to demonstrate the relationship between degree and radian measurement Have students compete graphic organizers for: 1. Angle measures expressed in degrees and radians 2. Values of sines, cosine and tangent functions for 0, 30, 45, 60 and 90 degree angles and their multiples Remind students to watch the signs of the six trig functions once they locate the reference angle.	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
F-TF.1 G-C.5	EQ.1	Find the length of an arc given the measure of the central angle.	Derive formulas for arc length using circumference of a circle. Angles must be converted from degree measure to radian measure. Note radius versus diameter.	

Unit 4 – Graphs of Trigonometric Functions Learning Plan

CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.1 G-C.5	EQ.1	Find the area of circular sector.	Derive formula for area of a circular sector using area of a circle. Remind students that area is always expressed in square units.	
F-IF.4	EQ.2	Determine if a function is Periodic	Introduce vocabulary, including Periodic function and period	
A-CED.2 A-REI.10 F-IF.4 F-IF.7 F-IF.7e	EQ.2	Sketch the graphs of the sine and cosine functions	Relate the unit circle to the graph of the sine and cosine functions Remind students the period for the basic sine and cosine function is 2π . Stress that the graph of $y=\sin x$ passes through (0,0) while the graph of $y=\cos x$ passes through the point (0,1). Utilize the graphing calculator to model the graphs Graph the sine and cosine functions for various periods	
A-SSE.1 A-SSE.1a A-SSE.1b	EQ.2	Find the amplitude and the periods for sine and cosine functions	Utilize a table of values and draw smooth curves to see the affects of amplitude and period	Have students explain how to alter the period and amplitude for the basic sine and cosine graph.
A-CED.2	EQ.2	Write equations of sine and cosine functions given the amplitude and the period	Have students start with the general form of the equation, $y = A \sin K\theta$ or $y = A \cos K\theta$	

Unit 4 – Graphs of Trigonometric Functions Learning Plan

CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
A-CED.2	EQ.2	Write equations of sine and cosine functions given a graph.	Emphasize how knowing the function value when $x=0$ and whether the function is increasing or decreasing helps determine the appropriate function	
A-SSE.1 A-SSE.1a A-SSE.1b F-BF.3	EQ.2	Find the phase shift and vertical translation for sine cosine functions.	Utilize the graphing calculator to explore a horizontal translation (phase shift) and vertical translation Provide formula for phase shift Review translations of basic functions Make the vertical shift (midline) first when graphing, then amplitude, period, and phase shift. Emphasize a constant is being added for vertical translation.	
A-SSE.1 A-SSE.1a A-SSE.1b A-CED.2	EQ.2	Write the equation of sine and cosine given the amplitude, period, phase shift, and vertical translation.	Emphasize starting with the basic equation, $y = A \sin(k\theta + c) + h$ or $y = A \cos(k\theta + c) + h$	
F-BF.3		Graph compound functions	Show how compound functions involving addition can be graphed separately and then the ordinates can be added to find the value of the new function	

Unit 4 – Graphs of Trigonometric Functions Learning Plan			
CCSS Standards	Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
N-Q.1 N-Q.2 N-Q.3 A-SSE.1 F-IF.4 F-IF.7 F-IF.7e F-TF.5	EQ.2	Model real-world data using sine and cosine functions.	Utilize a table of values Provide examples of situations where periodic behavior occurs, i.e. Meteorology, health, waves, etc... Make sure the calculator is in radian mode when graphing.
A-CED.2 F-IF.4 F-IF.5	EQ.2	<i>Graph, tangent, cotangent, secant and cosecant functions.</i>	<i>Utilize a table of values to discover the period for the tangent and cotangent curve is π.</i> <i>Review asymptotes</i> <i>Discuss the properties of each of the graphs.</i>
A-SSE.1 A-SSE.1a A-SSE.1b A-CED.2 F-BF.3	EQ.2	<i>Write equations of trigonometric functions.</i>	<i>Utilize the properties of the graphs for $y=\cot x$, $y=\csc x$, and $y=\sec x$.</i> <i>Notice the periods for $y=\sin x$, $y=\cos x$, $y=\csc x$, $y=\sec x$, VERSUS $y=\tan x$ and $y=\cot x$.</i>
A.CED.2 F-IF.4 F-IF.5 F-BF.4 F-BF.4d F-TF.6	EQ.3	<i>Graph inverse trigonometric functions.</i>	<i>Explain limitations on the domain and range of the inverse trigonometric functions</i> <i>Introduce principal values</i> <i>Have students write about the six Trigonometric functions, separating them into two categories – continuous functions and discontinuous functions. Have students write about the distinguishing characteristics of</i>

Unit 4 – Graphs of Trigonometric Functions

Learning Plan

CCSS Standards	Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
		<i>Emphasize that none of the inverses of the trigonometric functions are functions</i>	<i>each</i>

Unit 4 – Graphs of Trigonometric Functions

Common Learning Experiences and Assessments

• http://map.mathshell.org/materials/download.php?fileid=1284 – Sectors of circles • http://illuminations.nctm.org/Lesson.aspx?id=3151 – Rolling into radians (ACA only) • http://www.illustrativemathematics.org/illustrations/1647 - Exploring sinusoidal functions • http://www.101qs.com/2450-ferris-wheel# - Ferris Wheel • http://www.illustrativemathematics.org/illustrations/1415 - Model airplane acrobatics • http://www.illustrativemathematics.org/illustrations/816 - Foxes and Rabbits 2 • http://www.illustrativemathematics.org/illustrations/816 - Foxes and Rabbits 3

Unit 5 – Trigonometric Identities and Equations**Major Topics in this Unit:**

Basic Trigonometric Identities

Verifying Trigonometric Identities***Sum and Difference Identities******Double-Angle and Half-Angle Identities***

Solving Trigonometric Equations

Common Core State Standards in ConnecticutPower Standards are in **BOLD****A-CED.1 Create equations and inequalities in one variable and use them to solve problems.****A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with****A-REI.1 Explain each step in solving simple equations as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.**A-REI.11 Explain why the x-coordinate of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation $f(x)=g(x)$; find the solutions approximately, e.g., using technology to graph functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.F-BF.4a Solve an equation of the form $f(x)=c$ for a simple function f that has an inverse and write an expression for the inverse.

F-TF.7 (+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of a context.

F-TF.8 Prove the Pythagorean identity $\sin^2 \theta + \cos^2 \theta = 1$ and use it to find $\sin \theta$, $\cos \theta$, or $\tan \theta$ given $\sin \theta$, $\cos \theta$, or $\tan \theta$ and the quadrant of the angle.

F-TF.9 (+) Prove the addition and subtraction formulas for sine, cosine, and tangent and use them to solve problems.

Unit 5 – Trigonometric Identities and Equations

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Equations and inequalities in one variable ➤ Problems ❖ Equations in two or more variables ➤ Relationships between quantities ➤ Graph ▪ Coordinates axes ▪ Labels ▪ Scales ❖ Steps in solving simple equations ➤ Equality of numbers ➤ Original equation with solution ➤ Viable argument ➤ Solution Method ❖ Solution of the equation $f(x) = g(x)$ ➤ x-coordinate of intersection of functions $y = f(x)$ and $y = g(x)$ ▪ linear ▪ polynomial ▪ rational ▪ absolute value ▪ exponential ▪ logarithmic ❖ Equation of the form $f(x)=c$ that has inverse ➤ Expression for the inverse ❖ Trigonometric equations in modeling contexts ➤ Solutions ▪ Technology ▪ In terms of a context ❖ Pythagorean identity $\sin^2 \theta + \cos^2 \theta = 1$ ➤ $\sin \theta, \cos \theta, \tan \theta$ ➤ Quadrant of the angle ❖ Addition and Subtraction formulas ➤ Sine, cosine, and tangent ➤ Problems	❖ Create ➤ Solve ❖ Create ❖ Explain ➤ Construct ▪ Justify ❖ Explain (why) ➤ Use (technology) ▪ Graph (functions) ▪ Make (tables of value) ▪ Find (successive approximations) ❖ Solve ➤ Write ❖ Solve ➤ Evaluate ➤ Interpret ❖ Prove ➤ Find ❖ Prove ➤ Solve

Unit 5 – Trigonometric Identities and Equations

Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Trigonometric expressions can be simplified by replacing one expression with a reciprocal, quotient, Pythagorean, symmetry, or opposite angle, sum and difference, or half-angle identity. 2. Trigonometric equations can be solved using inverse functions. Solutions can be evaluated using technology and interpreted in terms of a context.	1. How can trigonometric expressions be simplified using identities? 2. How are trigonometric equations solved in modeling contexts?

Unit 5 – Trigonometric Identities and Equations

Learning Plan

CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.8	EQ.1	Identify and use reciprocal identities, quotient identities, Pythagorean identities and opposite-angle identities.	Introduce the five basic types of trigonometric identities: ▪ Reciprocal identities ▪ Quotient identities ▪ Pythagorean identities ▪ Symmetry identities ▪ Opposite-angle identities Remind students they can also use right triangles and the Pythagorean Theorem to find the trigonometric value. Show how the Pythagorean Identifies can be rewritten in additional forms. Review division of fractions.	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects

Unit 5 – Trigonometric Identities and Equations Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.8	EQ.1	Use the basic trigonometric identities to verify other identities.	Emphasize the various strategies including: ▪ Rewrite expressions in terms of sine and cosine first ▪ Substituting a basic trigonometric identity ▪ Factoring ▪ Multiplying ▪ Simplifying the complicated side Utilize a graphing calculator to investigate whether an equation may be an identity	<i>Have students explain why $\sin x = \cos x \tan x$ is an identity, but $\sin x = \frac{1}{2}$ is not.</i> <i>Express $\cos x$ in terms of each of the other trigonometric functions. each function should contain exactly one function other than the cosine.</i>
F-TF.9 (+)	EQ. 1	<i>Use the sum and difference identities for the sine, cosine, and tangent functions.</i>	<i>Have students identify multiples of 30, 45 and 60.</i> <i>Point out that by using known values for functions of special angles, an exact value can be found for the function of an angle, whereas the calculator gives a decimal approximation.</i> <i>Remind students that $\sin(x + y)$ is NOT $\sin x + \sin y$.</i>	
A-CED.1 A-REI.1 A-REI.11 F-BF.4a	EQ.2	Solve trigonometric equations.	Utilize graphing calculator to explore multiple solutions. Place different restrictions on the	

Unit 5 – Trigonometric Identities and Equations

Learning Plan

CCSS Standards	Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
F-TF.7		variable Make connections between solving algebraic equations and solving trigonometric equations. <i>Point out the additional forms of the Pythagorean Identities. Review factoring.</i>	

Unit 5 – Trigonometric Identities and Equations

Common Learning Experiences and Assessments

- <http://illuminations.nctm.org/hsactivity/> - Trigonometry for Solving Problems
- <http://map.mathshell.org/materials/download.php?fileid=846> – Short Tasks: Trigonometric Functions 1
- https://www.georgiastandards.org/Common-Core/Common%20Core%20Frameworks/CCGPS_Math_9-12_Pre-Calculus_Unit4SE.pdf - trigonometric identities

Unit 6 – Exponential and Logarithmic Functions**Major Topics in this Unit:**

Real Exponents
Exponential Functions
The Number e
Logarithmic Functions
Common Logarithms
Natural Logarithms
Modeling Real-World Data and Exponential and Logarithmic Functions

Common Core State Standards in ConnecticutPower Standards are in **BOLD**

N-RN.1 Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents.

N-RN.2 Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2 Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A-SSE.1 Interpret expressions that represent a quantity in terms of its context.

A-SSE.1a Interpret parts of an expression, such as terms, factors, and coefficients.

A-SSE.1b Interpret complicated expressions by viewing one or more of their parts as a single entity.

A-SSE.2 Use the structure of an expression to identify ways to rewrite it.

A-SSE.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3c Use the properties of exponents to transform expressions for exponential functions.

A-CED.1 Create equations and inequalities in one variable and use them to solve problems.

A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-REI.1 Explain each step in solving simple equations as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

A-REI.10 Understand that the graph of an equation in two variables is the set of all solutions plotted in the coordinate plane, often forming a curve (which could be a line).

A-REI.11 Explain why the x-coordinate of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation

Unit 6 – Exponential and Logarithmic Functions

$f(x)=g(x)$; find the solutions approximately, e.g., using technology to graph functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

F-IF.2 Use function notations, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F.IF.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of quantities, and sketch graphs showing key features given a verbal description of the relationship.

F.IF.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

F.IF.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

F-IF.7a Graph linear and quadratic functions and show intercepts, maxima, and minima.

F-IF.7b Graph square root, cube root, and piece-wise defined functions, including step functions and absolute value functions.

F-IF.7c Graph polynomial functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

F-IF.7d (+) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

F-IF.7e Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

F-IF.8 Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

F-IF.8b Use properties of exponents to interpret expressions for exponential functions.

F-BF.4 Find inverse functions.

F-BF.4a Solve an equation of the form $f(x)=c$ for a simple function f that has an inverse and write an expression for the inverse.

F-BF.5 (+) Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.

F.LE.4 For exponential models, express as a logarithm the solution to $ab^{ct} = d$, where a , c , and d are numbers and the base b is 2, 10, or 3; evaluate the logarithm using technology.

F-LE.5 Interpret the parameters in a linear or exponential function in terms of a context.

Unit 6 – Exponential and Logarithmic Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Definition of meaning of rational exponents ➤ Properties of integer exponents ➤ Notation for radicals in terms of rational exponents ❖ Expressions involving radicals and rational exponents ➤ Properties of exponents ❖ Units ➤ Problems ➤ Solution of multi-step problems ➤ Formulas ➤ Graphs ▪ Scale ▪ Origin ➤ Data Displays ❖ Descriptive modeling ❖ Level of accuracy ➤ Limitations on measurement ❖ Expressions that represent a quantity ➤ In terms of a context ➤ Parts ▪ Terms ▪ Factors ▪ Coefficients ➤ Complicated expressions ➤ One or more parts as a single entity ❖ Structure of expression ❖ Equivalent form of an expression ➤ Properties of quantity represented by expression ❖ Properties of exponents ➤ Expressions for exponential functions ❖ Equations and inequalities in one variable ➤ Problems ❖ Equations in two or more variables ➤ Relationships between quantities	❖ Explain ➤ Extends ❖ Rewrite ➤ Use ❖ Use (units) ➤ Understand ➤ Guide ➤ Choose ➤ Interpret ❖ Define (appropriate quantities) ❖ Report (quantities) ❖ Interpret ➤ View ❖ Use ➤ Rewrite ❖ Choose ➤ Produce ➤ Reveal ➤ Explain ❖ Use ➤ Transform ❖ Create ➤ Solve ❖ Create

Unit 6 – Exponential and Logarithmic Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ Graph ▪ Coordinates axes ▪ Labels ▪ Scales ❖ Steps in solving simple equations ➤ Equality of numbers ➤ Original equation with solution ➤ Viable argument ➤ Solution Method ❖ Graph of equation in two variables ➤ Set of all solutions ➤ Coordinate planeCurve (which could be a line) ❖ Solution of the equation $f(x) = g(x)$ ➤ x-coordinate of intersection of functions $y = f(x)$ and $y = g(x)$ ▪ linear ▪ polynomial ▪ rational ▪ Absolute value ▪ Exponential ▪ Logarithmic ❖ Function notation ➤ Input values for domain ➤ In terms of a context ❖ Function ➤ Relationship between two quantities ➤ Key features ▪ Graphs ▪ Tables ▪ Verbal description ❖ Domain of functions ➤ Graph ➤ Quantitative relationships ❖ Functions expressed symbolically ➤ By hand in simple cases ➤ Technology for complicated cases ❖ Functions ➤ Linear and Quadratic	❖ Explain ➤ Construct ➤ Justify ❖ Understand ➤ Plot ❖ Explain (why) ➤ Use (technology) ▪ Graph (functions) ▪ Make (tables of value) ▪ Find (successive approximations) ❖ Use (function notation) ➤ Evaluate (functions) ➤ Interpret (statements) ❖ Model (functions) ➤ Interpret (key features) ➤ Sketch (graphs) ❖ Relate ➤ Describe ❖ Graph (key features) ❖ Graph ➤ Show

Unit 6 – Exponential and Logarithmic Functions

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
▪ Intercepts ▪ Maxima ▪ Minima ➤ Polynomials ▪ Zeros ▪ Asymptotes ▪ Suitable factorizations ▪ End behavior ➤ Rational ▪ Zeros ▪ Asymptotes ▪ Suitable factorizations ▪ End behavior ➤ Exponential and Logarithmic ▪ Intercepts ▪ End behavior ➤ Trigonometric ▪ Period ▪ Midline ▪ Amplitude ❖ Function defined by an expression ➤ Equivalent forms ➤ Different properties of functions ❖ Properties of exponents ➤ Expressions for exponential functions ❖ Inverse functions ❖ Equation of the form $f(x)=c$ ➤ Expression for inverse ❖ Inverse relationship between exponents and logarithms ➤ Problems ▪ Logarithms ▪ Exponents ❖ Exponential models ➤ Solution to $ab^{ct} = d$ as logarithm ➤ Base b is 2, 10, or 2 ➤ Technology ❖ Parameters in a linear or exponential function	➤ Identify ❖ Write ➤ Reveal ➤ Explain ❖ Use ➤ Interpret ❖ Find ❖ Solve ➤ Write ❖ Understand ➤ Use ➤ Solve ❖ Express ➤ Evaluate ➤ Use ❖ Interpret

Unit 6 – Exponential and Logarithmic Functions Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
➤ In terms of a context	

Unit 6 – Exponential and Logarithmic Functions Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Radicals can be rewritten a rational exponent. Then you can apply product and quotient properties, Power of a Power, Power of a Quotient, and Power of a Product property to simplify expressions. 2. Graphs of exponential and logarithmic functions show intercepts and end behavior. The functions can be rewritten in equivalent forms to explain different properties of the function. 3. Exponential and logarithmic functions are inverses. Exponential functions can be rewritten as a logarithmic function and logarithms can be rewritten as exponential functions when solving.	1. How can you rewrite expressions involving radical and rational exponents? 2. How are key characteristics used to graph functions? 3. How is the relationship between exponential and logarithmic functions used to solve problems?

Unit 6 – Exponential and Logarithmic Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
N-RN.1 N-RN.2	EQ.1	Use the properties of exponents to simplify exponential expressions.	Review properties of integral exponents, including: Product Power of a Power Power of a Quotient Power of a Product Quotient	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
A-CED.1 A-REI.1 F-BF.4a	EQ.1	Solve equations containing rational exponents	Review the properties of rational exponents	
N-Q.1 N-Q.2 N-Q.3 A-CED.2 A-REI.10 F-IF.F-IF.54 F-IF.7 F-IF.7e	EQ.2	Graph an exponential function	Demonstrate how to graph exponential functions that model growth and decay Review the characteristics of domain, range, y-intercept, behavior, and asymptotes Utilize the graphing calculator to explore graphing exponential functions Compare a power function to an	

Unit 6 – Exponential and Logarithmic Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			exponential function. Remind students in an exponential function, the independent variable is in the exponent.	
A-SSE.1 A-SSE.1a A-SSE.1b A-SSE.3 A-SSE.3c A-CED.1 A-REI.11 F-IF.8 F-IF.8b F-LE.5	EQ.2	Solve problems involving exponential growth and decay	Define an exponential equation a $y = ab^x$ and review the concept of initial value and growth and decay factor. Provide examples of doubling, half life, and investment problems	
A-SSE.1 A-SSE.1a A-SSE.1b A-SSE.2 A-SSE.3 F-IF.8 F-IF.8b	EQ.2	Use the exponential function with base e.	Demonstrate on the graphing calculator how as $n \rightarrow \infty$ the graph of $y = (1 + \frac{1}{n})^n$ approaches the graph of $y=e$. Utilize continuously compounded interest formula.	
F-IF.8 F-IF.8b F-BF.5 F-LE.4	EQ.3	Convert from exponential form to logarithmic form and vice versa.	Have students discover the relationship between exponential and logarithmic forms by providing numeric examples and working toward developing the algebraic equations. Remind students that a logarithm is an	

Unit 6 – Exponential and Logarithmic Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			exponent.	
F-IF.2	EQ.3	Evaluate expression involving logarithms	Provide examples of common and natural logarithms and their properties Utilize the basic log properties and inverse logarithmic properties, including: $\log_b b = 1$ $\log_b 1 = 0$ $\log_b b^x = x$ $b^{\log_b x} = x$	
F-IF.8 F-IF.8b	EQ.3	Use the logarithmic properties simplify and expand logarithmic functions	Utilize the product, quotient power, and equality properties	
A-CED.1 A-REI.1 A-REI.11 F-BF.4a F-BF.5 F-LE.4	EQ.3	Solve a logarithmic equation.	Emphasize that it can be rewritten and solved as an exponential equation Provide examples with extraneous solutions and demonstrate checking	
A-CED.2 A-REI.10 F-IF.4 F-IF.5	EQ.2	Graph logarithmic functions	Compare and contrast graphing exponential functions and logarithmic functions Focus student attention how one is the inverse of the other Point out that the domain of a	

Unit 6 – Exponential and Logarithmic Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			logarithmic function is the set of all positive real numbers.	
F-LE.4	EQ.2	Find Common Logarithms	Review the properties of common logarithms Explain how the change of base formula can be used to evaluate a logarithm with a base other than base 10 and base e Remind student if the base is not written in logarithmic form, it is base 10. Utilize the change of base formula to find the value of a logarithm	
A-CED.1 A-REI.1 A-REI.11 F-BF.4a F-BF.5 F-LE4	EQ.3	Solve equations using common logarithms.	Demonstrate how common logarithms can be used to solve exponential equations. Remind students that logarithms in the real number system are undefined for negative numbers	
F-LE.4	EQ.3	Find natural logarithms.	Emphasize a logarithmic functions with base e is a natural logarithm Remind students that a logarithmic function with any base greater than zero and not equal to one can be changed to a function with a natural logarithmic base by using the change of	Compare and contrast the common and natural logarithmic functions, and give real-world examples of each.

Unit 6 – Exponential and Logarithmic Functions Learning Plan

CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			base formula. Review the properties of natural Logarithms Stress the ln of a number is an exponent.	
A-CED.1 A-REI.1 A-REI.11 F-BF.4a F-BF.5 F-LE.4	EQ.3	Solve equations using natural logarithms.	Emphasize that natural logarithms are to solve problems involving the number e Demonstrate how equations with natural Logarithms can be solved algebraically or graphically	
A-SSE.1 A-SSE.3 A-CED.1 F-LE.4 F-LE.5	EQ. 3	Solve real-world applications with common and natural logarithms.	Provide examples of real world data, i.e. height of children, sound intensity, heat in an enclosed vehicle, doubling time, etc... Utilize the graphing calculator to find the equation of best fit for data of an exponential data.	

Unit 6 – Exponential and Logarithmic Functions Common Learning Experiences and Assessments

- <http://www.illustrativemathematics.org/illustrations/1305> - Forms of exponential expressions (ACC only)
- <http://www.illustrativemathematics.org/illustrations/600> - Exponentials and Logarithms I

Unit 7 – Combinatorics and Probability**Major Topics in this Unit:**

Permutations and combinations
Permutations with Repetitions and circular permutations
probability and odds
probability of compound events
conditional probability

Common Core State Standards in ConnecticutPower Standards are in **BOLD**

S-CP.1 Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events (“or”, “and”, “not”).

S-CP.2 Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

S-CP.3 Understand the conditional probability of A and B given B as $P(A \text{ and } B) / P(B)$, and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.

S-CP.6 Find the conditional probability of A given B as the fraction of B’s outcomes that also belong to A, and interpret the answer in terms of the model.

S-CP.7 Apply the Addition Rule, $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$, and interpret the answer in terms of the model.

S-CP.8 (+) Apply the general Multiplication Rule in a uniform probability model, $P(A \text{ and } B) = P(A)P(B|A) = P(B)P(A|B)$, and interpret the answer in terms of the model.

S-CP.9 (+) Use permutations and combinations to compute probabilities of compound events and solve problems.

S-MD. 7 (+) Analyze decisions and strategies using probability concepts

Unit 7 – Combinatorics and Probability

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Events ➤ Subsets of a sample space ➤ The set of outcomes ➤ Characteristics of the outcomes, or as ▪ Unions – “OR” ▪ Intersections – “AND” ▪ Complements of other events – “NOT” ❖ Two events A and B are independent ➤ Probability of A and B occurring together ▪ Product of their probabilities ▪ Characteristics ❖ Conditional probability of A and B given B ➤ $P(A \text{ and } B) / P(B)$ ➤ Independence of A and B ▪ Conditional probability of A given B same as $P(A)$ ➤ Conditional probability of B given A ▪ Same as $P(B)$ ❖ Conditional probability of A given B ➤ Fraction of B's outcomes that also belong to A ❖ Addition Rule ➤ $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$ ➤ Answer in terms of the model ❖ The general Multiplication Rule in a uniform probability model ➤ $P(A \text{ and } B) = P(A)P(B A) = P(B)P(A B)$ ➤ Answer in terms of the model ❖ Permutations and combinations ➤ Probabilities of compound events ➤ Problems ❖ Decisions and strategies ➤ Probability concepts	❖ Describe ➤ Use ❖ Understand ➤ Use ➤ Determine ❖ Understand ➤ Interpret ❖ Find ➤ Interpret ❖ Apply ➤ Interpret ❖ Apply ➤ Interpret ❖ Use ➤ Compute ➤ Solve ❖ Analyze ➤ Use

Unit 7 – Combinatorics and Probability

Learning Plan

Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. Characteristics of the outcomes can include unions "or", intersections "and", or complements of other events "not". 2. Two events are said to be independent if the results of the second event is not affected by the result of the first event. If A and B are independent events, the probability of both events occurring is the product of the probabilities of the individual events if the result of one event IS affected by the result of another event, the events are said to be dependent. 3. If order doesn't matter, it is called a combination. If order does matter it is called a permutation. 4. If two events, A and B, are mutually exclusive, then the probability that A or B occurs is the sum of their probabilities. $P(A \text{ or } B) = P(A) + P(B)$. If two events, A and B, are inclusive, then the probability of A or B occurs is the sum of their probabilities decreased by the probability of both occurring. $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$	1. How can the subsets of a sample space be used to describe events? 2. How do independent and dependent events compare when computing probabilities? 3. How do permutations and combinations compare when computing probabilities of compound events? 4. How do finding mutually inclusive and mutually exclusive probabilities compare?

Unit 7 – Combinatorics and Probability Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
S-CP.9	EQ.3	Solve problems related to the Basic Counting Principle.	Use manipulatives to determine how many arrangements there are.	Pre-Assessment Do-Now's Formative assessment Oral questioning Checkpoint exercises Closure Exit tickets Homework Summative assessments Quizzes Tests Projects
S-CP.2	EQ. 2	Distinguish between dependent and independent events.	Focus on vocabulary: Dependent events and independent events.	
S-CP.9 (+)	EQ.3	Solve problems involving permutations or combinations.	Remind students that permutation means the same thing as an arrangement and that order is important in a permutation. Remind students that in a combination order is not important.	
S-CP.9	EQ.3	Determine the number of arrangements of objects using permutations.	Discriminate between linear and circular arrangements. Stress that if n people are seated	

Unit 7 – Combinatorics and Probability Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			around a revolving server, the resulting permutations are circular permutations with $(n - 1)!$ Circular permutations. Stress that if n people are seated around a merry-go-round on which one person's position is fixed, the resulting permutations are linear permutations with $n!$ linear permutations.	
S-CP.6	EQ.1	Find the probability of an event.	Stress that the word “not” will involve complements, and that the sum of the complements is 1. Remind students that the expression “one of more” has the same meaning as “at least one”. Remind students that $P(\text{success}) + P(\text{failure}) = 1$.	Why is the theoretical probability of an event not necessarily match the experimental probability for that event? How does the number of experiments affect how close the experimental probability is to the theoretical probability?
S-MD.7	EQ.1	Find the odds for the success and failure of an event.	Stress that the word “odds” represents a comparison of the possible outcomes, not the probability of one outcome.	Ask students to explain how to find the odds and the probability that an event will occur.
S-CP.8	EQ.2	Find the probability of independent and dependent events.	Have students give examples of independent and dependent events. Emphasize replacement versus non-replacement.	
S-CP.1	EQ.4	Identify mutually exclusive events.	Be sure that students understand the difference between mutually exclusive	

Unit 7 – Combinatorics and Probability Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			events and dependent events. Emphasize the difference between an “AND” situation and an “OR” situation	
S-CP.7	EQ.4	Find the probability of mutually exclusive and inclusive events.	Have students illustrate the situation with a Venn diagram in order to determine each type.	Have students describe how to find the probability of inclusive events.
S-CP.3	EQ.4	Find the probability of an event given the occurrence of another event.	Encourage all students to list all possibilities (sample space). Stress the probability of A given B has a different meaning from the probability	

Unit 7 – Combinatorics and Probability

Common Learning Experiences and Assessments

- <http://www.illustrativemathematics.org/illustrations/949> - The Titanic 1
- <http://www.illustrativemathematics.org/illustrations/950> - The Titanic 2
- <http://www.illustrativemathematics.org/illustrations/951> - The Titanic 3
- <http://www.illustrativemathematics.org/illustrations/1112> - Rain or Lightning
- <http://www.illustrativemathematics.org/illustrations/1035> - Alex, Mel, and Chelsea play a game
- <http://map.mathshell.org/materials/download.php?fileid=1275> – Medical testing
- <http://www.illustrativemathematics.org/illustrations/1333> - But Mango is my favorite
(calculate the probability of intersection events)
- https://www.georgiastandards.org/Common-Core/Common%20Core%20Frameworks/CCGPS_Math_9-12_Pre-Calculus_Unit7SE.pdf
- probability

Unit 8 – Conics**Major Topics in this Unit:***Circles**Ellipses**Hyperbolas***Common Core State Standards in Connecticut**Power Standards are in **BOLD****A.SSE.2 Use the structure of an expression to identify ways to rewrite it.****A-SSE.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.**

A-REI.10 Understand the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line.)

G-GPE.1 Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

G-GPE. 3(+) Derive the equations of the ellipses and hyperbolas given the foci, using the fact that the sum or difference of differences from the foci is constant.

Unit 8 – Conics

Unwrapped Performance Standards

Unwrapped Standard: Concepts	Skills
❖ Structure of an expression ❖ Equivalent form of an expression ➤ Properties of a quantity ❖ Graph of an equation in two variables ➤ Set of points plotted in the coordinate plane ➤ Curve (which could be a line) ❖ Equation of a circle ➤ Given center and radius ▪ Complete the square ➤ Pythagorean Theorem ❖ Equations of ellipses and hyperbolas ➤ Given foci ➤ Sum or difference from foci is constant	❖ Use ➤ Rewrite ❖ Choose ➤ Produce ➤ Reveal ➤ Explain ❖ Understand ❖ Derive ➤ Use ❖ Derive

Unit 8 – Conics Learning Plan	
Big Ideas Student's statements of enduring ideas	Essential Questions Teacher's guiding question
1. A circle is the set of all points in the plain that are equidistant from the center. The equation is $(x-h)^2 + (y-k)^2 = r^2$ where (h,k) is the center of the circle and r is the radius. Derive the formula using the Pythagorean Theorem. 2. An ellipse differs from a circle in that it does not have a constant radius. An ellipse has two focal points in which the sum of the length of both focal points to any given point on the ellipse is always the same. The equation is $\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$, where (h, k) is the center of the ellipse and a is the distance from center to the ellipse on the x-axis. The set of points in a plane whose distances to two fixed points in the plane have a constant difference. 3. The hyperbola consists of two branches, The equation of a hyperbola is $\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$, where (h, k) is the center between the curves and a and b are used to find the asymptotes of the graph.	1. How do you derive the equation of a circle given the center and radius? 2. How do you derive the equation of ellipse given the foci? 3. How do you derive the equation of hyperbola given the foci?

Unit 8 – Conics Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
A-SSE.2 A-SSE.3 G-GPE.1	EQ.1	<i>Use and determine the standard and general forms of the equation of a circle.</i>	<i>Focus on vocabulary.</i> <i>Compare standard form and general form.</i> <i>Note that (x-h) shifts the graph h units horizontally and y-k shifts the graph vertically.</i>	
A-REI.10 G-GPE.1	EQ.1	<i>Graph circles.</i>	<i>Review completing the square.</i> <i>Make sure that students substitute the x- and y- values of the given point into the h and k variables, not the x and y variables.</i>	
A-SSE.2 A-SSE.2 G-GPE.3	EQ. 2	<i>Use and determine the standard form and general forms of the equation of an ellipse.</i>	<i>Stress vocabulary.</i> <i>Caution students not to confuse relationship that holds in an ellipse with the Pythagorean Theorem.</i>	
A-REI.10 G-GPE.3	EQ. 2	<i>Graph ellipses.</i>	<i>Compare standard form, orientation, and description.</i> <i>Emphasize the importance of determining the orientation of the ellipse before writing the standard form of the equation.</i> <i>Suggest that students list the values of a, b, c, h, and k as a first step.</i>	

Unit 8 – Conics Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Bases on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
			<i>Make sure students do not forget to multiply the coefficient when balancing terms as they complete the square.</i> <i>Remind students that when they solve for y, they will get both a positive and negative expression.</i>	
A-SSE.2 A-SSE.3 G-GPE.3	EQ.3	<i>Use and determine standard and general forms of the equation of a hyperbola.</i>	<i>Stress vocabulary.</i> <i>Point out that for hyperbolas, a, b, and c are related to the Pythagorean Theorem, unlike ellipses.</i>	
A-REI.10 G-GPE.3	EQ.3	<i>Graph hyperbolas.</i>	<i>Compare standard form, orientation, and description.</i> <i>Stress the importance of asymptotes and vertices of the hyperbola.</i> <i>Students can find a and b from the standard form of the equation and use them to draw the rectangle whose diagonals are the asymptotes.</i>	<i>Ask students to compare and contrast hyperbolas and ellipses. Include discussions of standard forms of equations, graphs, axes, foci, vertices, and centers.</i>

Unit 8 – Conics

Common Learning Experiences and Assessments

- <http://www.illustrativemathematics.org/illustrations/1425> - Explaining the equation for a circle
- <http://illuminations.nctm.org/Lesson.aspx?id=2907> – Cutting conics
- <http://illuminations.nctm.org/Lesson.aspx?id=3003> – Human conics
- <http://www.shodor.org/interactivate/activities/ConicFlyer/> - Conics graphing app
- https://www.georgiastandards.org/Common-Core/Common%20Core%20Frameworks/CCGPS_Math_9-12_Pre-Calculus_Unit1SE.pdf
- Conics

Additional Recourses for All Units

- <http://illuminations.nctm.org/Activity.aspx?id=3520> – Function matching
- [Translations and parent graphs](#)
- <http://www.lessonplanet.com/lesson-plans/algebra-ii>
- <http://education.ti.com/calculators/downloads/US/Activities/Detail?ID=6604&MICROSITE=ACTIVITYEXCHANGE>
- <http://map.mathshell.org/materials/index.php>
- <http://ccssmath.org/>
- www.ccsstoolbox.org
- <http://insidemathematics.org/>
- High School Flip Book - <http://katm.org/wp/wp-content/uploads/flipbooks/High-School-CCSS-Flip-Book-USD-259-2012.pdf>
- <http://www.illustrativemathematics.org/standards/hs>
- <http://education.ti.com/calculators/downloads/US/Activities/Search/>
- <http://learnzillion.com/>
- <http://www.uen.org/core/math/7-12.shtml>
- <http://illuminations.nctm.org/>
- <http://www.khanacademy.org/>
- <http://blog.mrmeyer.com/>
- <http://www.dlt.ncssm.edu/stem/math-secondary>

PRECALCULUS

Approval requested for curriculum revision
Student Achievement Committee

May 21, 2014

Lisa Bernabe
K-12 Math Supervisor

Rationale: College and Career Readiness

Bristol Public School's Mission Statement

To maintain a safe and secure learning environment that provides all students with the necessary knowledge and skills to successfully complete college, other post high school education, or training.

- Vertical alignment to district curricula and Common Core State Standards
- Pre-requisite course for Calculus for Grade 11 students
- Fourth-year math course for Grade 12 students



Instructional Focus in Critical Areas

- ⦿ Functions and graphs*
- ⦿ Polynomial, rational, and radical relationships*
- ⦿ Trigonometry of general triangles and trigonometric functions
- ⦿ Exponential and logarithmic functions
- ⦿ Applications of probability*
- ⦿ Conic sections (accelerated only)*

*Indicates areas with new content objectives.

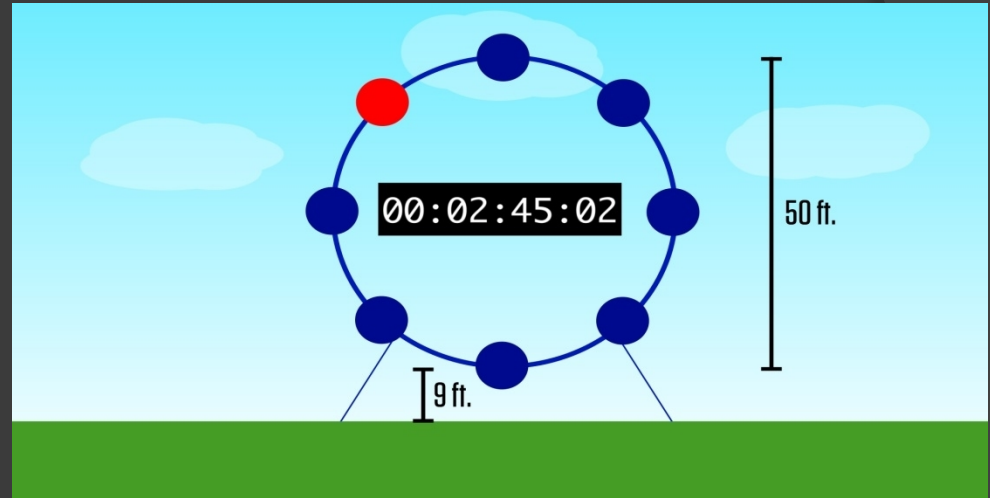
Overview of the Traditional Pathway for the Common Core State Mathematics Standards

	Domains	High School Algebra I	Geometry	Algebra II	Fourth Courses
Functions	Building Functions	- Build a function that models a relationship between two quantities. <i>For F.BF.1, 2, linear, exponential, and quadratic</i> F.BF.1a, 1b, 2 - Build new functions from existing functions. <i>Linear, exponential, quadratic, and absolute value; for F.BF.4a, linear only</i> F.BF.3, 4a		- Build a function that models a relationship between two quantities. <i>Include all types of functions studied</i> F.BF.1b - Build new functions from existing functions. <i>Include simple radical, rational, and exponential functions; emphasize common effect of each transformation across function types</i> F.BF.3, 4a	- Build a function that models a relationship between two quantities. (+) F.BF.1c - Build new functions from existing functions. (+) F.BF.4b, 4c, 4d, 5
	Linear, Quadratic, and Exponential Models	- Construct and compare linear, quadratic, and exponential models and solve problems. F.LE.1a, 1b, 1c, 2, 3 - Interpret expressions for functions in terms of the situation they model. <i>Linear and exponential of form $f(x)=b^x+k$</i> F.LE.5		Construct and compare linear, quadratic, and exponential models and solve problems. <i>Logarithms as solutions for exponentials</i> F.LE.4	
	Trigonometric Functions			- Extend the domain of trigonometric functions using the unit circle. F.TF.1, 2 - Model periodic phenomena with trigonometric functions. F.TF.5 - Prove and apply trigonometric identities. F.TF.8	- Extend the domain of trigonometric functions using the unit circle. (+) F.TF.3, 4 - Model periodic phenomena with trigonometric functions. (+) F.TF. 6, 7 - Prove and apply trigonometric identities. (+) F.TF. 9

Standards for Mathematical Practice:

Make sense of problems and persevere in solving them.

- How high will the red cart be off the ground at the end of the ride?



- How many complete spins do you think the red car will take on its ride?
- How long should a ride last so the person ends at the bottom for an easy exit?
- If the Ferris wheel spun backwards, how would that change your periodic function and your calculation?
- Where else would periodic functions make sense as a model?

Academic versus Accelerated

Subject: Math

Course: Pre-Calculus

Unit 2 – Polynomial and Rational Functions Learning Plan				
CCSS Standards		Objectives The students will be able to:	Instructional Strategies Based on our department philosophy for student learning, mathematics teachers will:	Common Learning Experiences and Assessments Through these assessments/experiences, students will demonstrate mastery of the learning objectives. Teachers will assess and provide feedback to students about the following:
A-REI.11	EQ.3	Approximate the real zeros of a polynomial function.	Locate zeros in a table or graph as the values of the functions go from positive to negative or negative to positive. Remind students that imaginary zeros cannot be approximated from a table or graph. Stress the word <i>approximate</i>. Utilize the graphing calculator.	
A-REI.1 A-REI.2 A-REI.11 F-BF.4a	EQ.5	Solve rational equations and Inequalities.	Look to factor polynomials to simplify the problem. Write down any impossible solutions before solving a rational equation. Stress the denominator can never be zero.	
A-REI.1 A-REI.2 A-REI.11 F-BF.4a	EQ.5	Solve radical equations.	<i>Remind students of the possibility of extraneous solutions when squaring both sides.</i> Remind students that odd roots can be negative, while even roots cannot be negative.	Have students explain the major steps involved in solving a radical equation that contains only one radical. <i>Then, have them compare this to the steps necessary if two radicals are present.</i>

Financial Implications

- 3 substitute teachers x \$75 per day x 2 days = \$450
- 2 teachers x 2 hours x \$20 per hour = \$80
- Total = \$530

Thank you

To the teachers who worked on the Bristol students to revise the precalculus curriculum.

- Kara Jones, Mike Beaudoin, and Molly Doub – Bristol Eastern High School
- Monika Frant and Dave Greenleaf – Bristol Central High School

Textbook Recommendation to the Board of Education

Subject/Course: AP Biology

Grade Level: 11-12

First Presentation BOE Meeting Date: May 7, 2014

Second Presentation BOE Meeting Date: June 4, 2014

Describe need for the textbook/materials: The College Board is requiring the district to update the textbook for AP Biology.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total	Readability
AP Biology	Campbell Biology 10 Edition	Reece, Urry, Cain, Wasserman, Minorsky, Jackson	10	2014	Benjamin Cummings	N/A	11.8-12
AP Biology	Campbell Biology in Focus	Urry, Cain, Wasserman, Minorsky, Jackson, Reece	1	2014	Pearson	N/A	11.2-14.8

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
AP Biology	Campbell Biology in Focus	Urry, Cain, Wasserman, Minorsky, Jackson, Reece	1	2014	Pearson	Glenview, IL	www.PearsonSchool.com/Advanced

Reasons for recommendation (include information on match to curriculum concepts and skills): See Attached Curriculum Frameworks

Campbell's Biology In Focus text is recommended for the Advanced Placement Biology courses at Bristol Central and Bristol Eastern. This textbook is updated to better reflect the new AP Biology curriculum put into place during the 2012-2013 school year. The text includes multiple opportunities for students to focus on core concepts and skills, including scientific inquiry and skills exercises, research methods, graphical analyses, and more. In addition, the online resources that go with the text are rich, including **Mastering Biology**, an online assessment and tutorial program which provides extensive opportunities for students to practice their scientific skills, make connections across curriculum, analyze data, view pertinent videos and animations based on content, take online quizzes and assessments, and more. Overall, this companion resource is a powerful textbook program that will help our students' better focus on the Advanced Placement curriculum and widen their depth of knowledge in the life sciences.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
100	Biology in Focus	\$130.47	\$13,047.00	50/50
100	Biology in Focus Student Study Guide	\$25.47	\$2,547.00	50/50

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
2	Exam View CD	\$50.97	(free with purchase)	1/1
2	IRDVD	\$200.97	(free with purchase)	1/1
2	Study Guide	\$25.47	(free with purchase)	1/1
2	Study Card	\$4.97	(free with purchase)	1/1
2	Spanish Glossary	\$12.47	(free with purchase)	1/1

TOTAL COST	
Total Cost for Student Texts/Materials	\$15,594.00
Total Cost for Teacher Materials	\$0 (Teacher materials are included free with order)
GRAND TOTAL (+ 8% shipping and handling)	\$16,841.52

Textbook Selection Committee		
Staff member	School	Grade/Course Taught
Nancy Lennon	Bristol Central High School	11/12
Erin Meyer	Bristol Eastern High School	11/12



Textbook Recommendation to the Board of Education

Subject/Course: Science /AP Chemistry

Grade Level: 10 -12

First Presentation BOE Meeting Date: May 7, 2017

Second Presentation BOE Meeting Date: June 4, 2014

Describe need for the textbook/materials: College Board has revised the framework as of 2013-14 and a new textbook that is aligned with the standards is needed.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total	Readability
AP Chemistry	Chemistry	Zumdahl & Zumdahl	9 th	2015	Cengage	43/51	12-14
AP Chemistry	Chemistry: The Central Science	Brown , LeMay, et. al	13 th	2015	Pearson	49/51	12-14

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
AP Chemistry	Chemistry: The Central Science	Brown, LeMay, et. al	13 th	2015	Pearson		http://www.pearsonschool.com/

Reasons for recommendation (include information on match to curriculum concepts and skills):

Chemistry: The Central Science is aligned with the College Board AP Chemistry framework. We find this book to be organized in a way that makes it more readable to high school students. Also included is an e-book and online resources that will allow students to watch animations and complete their homework on line, thus simulating the college experience. The online component allows for more individualized learning and will help teachers meet the needs of each student in their classes.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
120	Chemistry: the Central Science (includes e-book and online resources for 6 years)		\$19,825 (includes shipping)	60

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
2	Teacher Resources including: on line support, Test Prep Book, Exam View, Instructor's Resource manual, IR DVD, Test Generator, Solutions for Red and Black problems, Study Guide, Teacher Solutions, Student edition lab experiments	FREE	\$0	1 set

TOTAL COST	
Total Cost for Student Texts/Materials	\$19,825
Total Cost for Teacher Materials	\$0
GRAND TOTAL	\$19,825

Textbook Selection Committee		
Staff Member	School	Grades/Course Taught
Melanie Vetrano	BEHS	10-12 Chemistry
Laura Landro	BCHS	10 -12 Chemistry

AP Physics C Electricity and Magnetism Audit Outline

Primary Textbook: (Every student is provided with a copy)

Halliday, Resnick, and Walker, Fundamentals of Physics, 8th Edition, 2008

Supplementary Textbooks: (Students do not have copies of these, but materials and approaches are used from them)

- Giancoli, Physics, 4th edition
- Sears, Zemansky, Young, University Physics, 5th edition complete
- Crummett, Western, University Physics, Free Copy 1994
- Cutnell, Johnson, Physics, 3rd edition
- Feynman, et al, Feynman Lectures on Physics, Addison Wesley 1970
- E. Mazur, Peer instruction, A User's Manual, Prentice Hall, 1997
- White and Manning, Experimental College Physics, 3rd edition
- Cioffari, Edmunds, Experiments in College Physics, 6th edition
- Any other related texts from undergraduate, and graduate physics courses.

Supplementary Materials:

- Ideas occasionally taken from “The Physics Teacher”, AAPT publication
- The College Board Website
- Hand-outs and materials from College Board seminars including released AP multiple-choice, and free-response questions, and Teacher's guide.
- AP Physics Lab Guide

Audio-Visual/Computer Supplements:

- 6 networked computers in lab run Vernier Logger Pro 3 which is used to make graphs and analyze data.
- “The Mechanical Universe” and “Beyond the Mechanical Universe” video series from Cal. Tech. Videos are shown throughout the year to give historical, and alternate points of view.
- “Frames of Reference” Video
- PhET computer simulations and accompanying inquiry-based exercises.

General Course Description:

- Town has 2 high schools, and AP physics B is currently offered at both. The physics teachers at both schools meet frequently to discuss and share ideas.
- The physics teachers at each school are proposing to implement Physics C at both schools. The course is not currently offered. This document was jointly created by the two physics teachers.
- AP physics is the first physics course taken by students at my school.
- AP Calculus will be a co-requisite for this course, however the concepts of differentiation and integration will be covered by this course within the context of physics applications.
- We have an A/B day Block schedule, with four 85-minute periods a day, and Wednesday classes meet for 79 minutes.
- AP Physics meets every day for the whole year.
- AP Physics C Mechanics will be covered in the fall/winter, and AP Physics C Electricity and Magnetism will be covered in the winter/spring. The pace of the courses will include time for review and exam preparation.
- Labs are done on any day as required by curriculum
- We have a separate physics lab room that is connected to the physics room.
- Homework is typically assigned every night.
- Pacing is calculated from percentages per topic on the course outline in Acorn Book multiplied by the number of class meetings until AP exam in May.
- Due to the length of the class, students are sometimes given time to work together in groups on problems. This use of class time for group work becomes more frequent as the exam date nears. I encourage the students to form study groups outside of class, as an essential way to learn, and also as practice for next year in college. Very often students meet in groups to prepare the night before quizzes. This helps to satisfy the student-centered requirement.
- A few times a year, special homework assignments are given about one week before quiz. Students can gain points on the quiz by doing a certain number of problems. This type of assignment further encourages students to work together.

Physics Laboratory:

Labs generally fall into two categories. Some labs are designed so that the student can discover a physical principle that has not yet been formally introduced to them by the teacher. Other labs verify principles that the student has already been exposed to. Occasionally students go into lab to quickly obtain data for analysis in the classroom. Due to time constraints, and lack of student experience, full-fledged inquiry student-designed labs are not attempted. We do a mixture of “traditional labs” in which students are provided with explicit instructions, (which are still popular in colleges), and more modern “guided inquiry labs” where students have more freedom to determine the exact procedure, and experimental set up. Labs of this type help to satisfy the guided inquiry

and student-centered learning requirements. Due to the A/B block scheduling, we do not have to wait for a lab period. We have the freedom to do labs at any time. However over the semester, we average at least a day a week in lab with hands on experiments. Thus, lab work takes up roughly 20% of our class time. To further enhance the inquiry nature of the course we have begun to insert exercises from the PhET computer simulations available online. These quality simulations provide an excellent opportunity for student centered work. We will select from pre-made “labs” for this purpose, and will add more of our own written exercises in the future.

Since the first version of this Audit, our departments have obtained a class set of Vernier LabQuest hand-held data collection interfaces, assorted physics sensors, and Logger Pro 3 data collection and analysis software. I am ordering additional physics sensors including magnetic field sensors for next year. Finally, the two physics teachers have made a serious effort to pool our lab equipment, thus allowing us to do more lab activities.

- There is a separate lab room, which is connected to the physics room.
- Labs are done on any day as required by the curriculum.
- Students keep a portfolio of completed labs.
- A sample lab is included at the end of this document.

Assessments:

- At least 3 full period tests are given each marking period.
- Tests include problems from previously released AP Physics C exams.
- Open-ended questions, such as those found in Peer Instruction by Eric Mazur are sometimes included on quizzes. This helps to satisfy the student-centered requirement.

AP Physics C Electricity and Magnetism Course Outline:

Unit 1: Static Electricity

Charge and charging, conductors and insulators, conservation of charge
Point charges, Coulomb’s Law and superposition
Electric Fields, superposition, and uniform electric fields
Lines of force, electric flux, Gauss’s Law as the first Maxwell Equation
Electric fields of continuous charge distribution

The typical static demonstrations are done, including pith balls, electroscope, etc...to stimulate class discussion.

Electric potential of point charges, continuous charge distributions, and uniform electric fields

LAB: EQUIPOTENTIAL SURFACES AND LINES OF FORCE (Traditional and inquiry) Students map electric fields by mapping equipotential surfaces, and drawing in lines of force perpendicular to equipotential surfaces. After doing the dipole and parallel plates, students design their own charge configuration and predict the resulting equipotential surfaces and lines of force. The instructor then produces the configuration, and the students experimentally check it the next day.

Capacitance and capacitors
Parallel plate, cylindrical, and spherical capacitor
Dielectrics, polarization, and its effects on capacitance
Energy stored in a capacitor

Inquiry activity: PhET Capacitor simulation and “The Two Plate Special” exercise written by Hewitt/Baird.

Unit 2: Current Electricity

Electric current and potential difference
Ohm’s Law and resistance
Electric energy

LAB: OHM’S LAW (Traditional) Students get practice connecting series circuits, using volt and ammeters, and determine resistance of various resistors.

LAB: RESISTANCE OF WIRES (Traditional) Students analytically determine the resistance of a wire of known length, cross-sectional area and material. Then they measure its resistance as part of a circuit, and compare result to calculation.

LAB: THE ELECTRICAL EQUIVALENCE OF HEAT (Inquiry) Using water in a Styrofoam cup, students are directed to design an experiment to verify the amount of energy dissipated by a resistor.

Unit 3: DC Circuits

Kirchhoff’s Rules
Circuits with resistors
Circuits with resistors and/or capacitors
RC circuits and time constants

LAB: SERIES/PARALLEL CIRCUITS (Traditional) Students connect series and parallel circuits and verify current and voltage relationships discussed in class.

LAB: SERIES/PARALLEL LIGHTBULBS (Inquiry) Students design a series/parallel combination circuit using lightbulbs as resistors, and predict what happens to bulb brightness when each bulb is removed (unscrewed). They then check their results experimentally.

LAB: KIRCHHOFF'S RULES (Inquiry) Students design series/parallel circuits with with more than one emf, and calculate the currents using Kirchhoff's rules. They then connect the circuits in lab and verify their results.

LAB: RC CIRCUITS (Traditional) Attached as sample lab at the end of this document

LAB: WHEATSTONE BRIDGE (Traditional) Students construct wheatstone bridge and measure unknown resistances, including ammeter and voltmeter resistance.

Unit 4: Magnetic Fields

- Magnetism, poles, lines of force, and fields
- Gauss's Law for magnetic fields as Maxwell's second equation (no magnetic monopoles)
- Magnetic forces on moving electric charges
- Magnetic forces and torques on current carrying conductors
- Magnetic fields of current-carrying conductors and the Law of Biot and Savart.
- Ampere's Law as (almost) Maxwell's third equation

LAB: MAPPING MAGNETIC FIELDS (Traditional) Students sprinkle iron filings to investigate the shape of permanent magnets and current-carrying conductors.

LAB: CURRENT BALANCE (Class lab) The current balance is used to determine a value for the permeability of free space.

LAB: AP Physics Lab Guide Lab Ten MAGNETIC FIELDS (Inquiry) Students determine magnetic fields of loops of wires and of the Earth. In addition students determine the magnetic field of a solenoid.

Unit 5: Electromagnetism

- Magnetic flux
- Faraday's Law as Maxwell's fourth equation
- Induced currents and Lenz's Law
- Motional emf
- Self-inductance and inductors
- Circuits with inductors

Lab: TRANSFORMERS (Traditional) Students investigate transformers by performing several short experiments using LEYBOLD-HERAEUS Science Teaching Modules (STM) for Electromagnetism and induction.

Inquiry activity: PhET Faraday's Law simulation and worksheet (to be written next year).

Unit 6: AC circuits and Maxwell's equations

RL circuits

LC circuits

Maxwell's generalization of Ampere's Law and Maxwell's equations as a foundation for electricity and magnetism

LAB: LR, LC, and RLC Circuits: (Traditional) Students examine AC voltage, currents and their phase relationships for various series circuits, including RLC, using an oscilloscope.

Unit 7: Review and Exam Preparation (Student Centered)

Review

Practice and present released exam questions

Students work in pairs to prepare solutions, which are presented to the class. A student-lead discussion of big ideas and a question and answer round follow

Students evaluate their strengths and weaknesses

Sample Lab

RC Circuits*

(Discharge of a Capacitor)

Preceding experiments dealt with circuits in which currents and potential differences did not vary with time except possibly for variations due to changes in resistance with temperature and variations due to changes in the terminal voltages of seats of emf, resulting from polarization. In this experiment the capacitor will be used as a circuit element which will lead to the concept of time varying charges, currents, and potential differences.

As shown in your text, when an uncharged capacitor C is charged through a resistance R by an emf $\mathcal{E}$, the charge on the capacitor at a time t after the initiation of the process is given by the equation:

$$q = c\mathcal{E} \left(1 - e^{-\frac{t}{RC}} \right) \quad (1)$$

Similarly, it is shown that when a capacitor C is discharged through a resistance R , the charge remaining on the capacitor at a time t is:

$$q = q_0 e^{-\frac{t}{RC}} \quad (2)$$

Where q_0 is the initial charge on the capacitor, i.e. when $t = 0$.

Since $C = qV$, equation 2 may be written as:

$$V = \frac{q_0}{C} e^{-\frac{t}{RC}} = V_0 e^{-\frac{t}{RC}}$$

Where V is the potential difference across the cap at a time t and V_0 is the potential difference across when $t = 0$.

There are various ways in which the discharge of a capacitor may be studied. For example, making use of Ohm's Law, one could rewrite the above equation as:

$$i = i_0 e^{-\frac{t}{RC}}$$

One could charge the capacitor and then connect to it, in series, a high resistance and ammeter and observe the current in the circuit as a function of time.

In the present experiment a capacitor will be charged to a known potential difference and then discharged through a high resistance voltmeter connected across its terminals. The

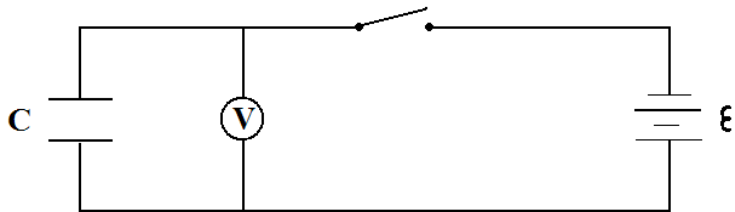
variation of the voltage with time will be observed and plotted. Note that, since a voltmeter is essentially an ammeter with a high resistance in series, this method is basically the same as the first mentioned method.

Apparatus:

- 1 voltmeter
- 1 power supply
- 1 switch
- 6 connection leads
- 1 timer
- 2 capacitors

Procedure:

1. Set the dial on the voltmeter for the 200 VDC. In this setting, its resistance will be sufficiently high so that the capacitor discharges slowly enough to record its values at different times. You will need to determine a method for finding the resistance R of the meter with this setting.
2. Connect the apparatus using one of the capacitors according to the following circuit design.



3. After your instructor has checked the circuit, close the switch and charge the capacitor.
4. Open the switch and, without recording any data, observe the time variation of the potential difference across the capacitor and decide on what time increments should be used so that several readings of the voltage can be made during the discharge of the capacitor.
5. Charge the capacitor again. Open the switch and record V vs. t during the discharge of the capacitor.
6. Plot the data on regular graph paper with t on the x-axis and V on the y-axis.
7. On semi-log paper, plot V vs. t again in the same manner. Your instructor will explain the use of semi-log paper.

8. The time constant of the circuit t_c is defined as the time it takes q (or V) to reach $1/e$ of its maximum value when the capacitor is discharging. Determine the time constant from your graphs. Compare with the value calculated from $t_c = RC$.
9. Show mathematically that the time constant t_c is given by $t_c = RC$.
10. Sketch the curves of q vs. t and i vs. t for the discharge of a capacitor.
11. What quantity is represented by the slope of the q vs. t curve at any instant?
12. The product of the slope of the V vs. t curve, multiplied by C , gives what?
13. Prove that the area under the curve of the i vs. t curve is equal to q_0 . If one measured this area, what additional information would be required to determine the value of an unknown capacitor?
14. Sketch a V vs. t curve for a capacitor during the charging process.
15. Repeat parts 2 to 8 using both capacitors in parallel.
16. Given, $\mathcal{E} - R \frac{dq}{dt} - \frac{q}{C} = 0$ derive equation (1)
17. Given $R \frac{dq}{dt} = -\frac{q}{C}$ derive equation (2)

*from SUNY-ALBANY physics 221 lab manual

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Textbook Recommendation to the Board of Education

Subject/Course: AP Physics 1

Grade Level: 11-12

First Presentation BOE Meeting Date: June 4, 2014 **Second Presentation BOE Meeting Date:** July 2, 2014

Describe need for the textbook/materials: The College Board is discontinuing the AP Physics B course and AP Physics 1 is the replacement. This textbook will be used in the Physics 1 class.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total
AP Physics 1	Physics: Principles with Application	Douglas Giancoli	6th	2014	Pearson	41/54
AP Physics 1	College Physics: A Strategic Approach	Knight, Jones, & Field	3rd	2015	Pearson	49/54

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
AP Physics 1	College Physics: A Strategic Approach	Knight, Jones, & Field	3rd	2015	Pearson	Boston	www.pearson.com

Reasons for recommendation (include information on match to curriculum concepts and skills):

Chapters match AP Frameworks with end of chapter problems progressively increasing in sophistication. Order of physics topics is rock solid and will support instruction. Text appears to meet industry standards and included simulations and real world applications. The book will assist students interested in careers as engineers, or scientists. Online resources provides support for completing homework and conducting research.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
120	College Physics: A Strategic Approach	\$153.00	\$18,360.00	60 to BC, 60 to BE
	Course Mate eBook, Enhanced Web Access	No charge		

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
	Included in Enhanced Web Access	No charge		

TOTAL COST	
Total Cost for Student Texts/Materials	\$18,360.00
Total Cost for Teacher Materials	
GRAND TOTAL	\$18,360.00

Textbook Selection Committee		
Staff member	School	Grade/Course Taught
David Brewer	Bristol Central	Physics 11-12
David Bittel	Bristol Eastern	Physics 11-12



Textbook Recommendation to the Board of Education

Subject/Course: Environmental Science ACA

Grade Level: 11/12

First Presentation BOE Meeting Date:

Second Presentation BOE Meeting Date:

Describe need for the textbook/materials: updated and revised curriculum. Existing text does not contain recent environmental events.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total	Readability
Env Sci ACA	Global Science		7	2009	Kendall Hunt		7-9
Env Sci ACA	Environmental Science Your World, Your Turn	Jay Withgott	1	2011	Pearson		9-10

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
Env Sci ACA	Environmental Science Your World, Your Turn	Jay Withgott	1	2011	Pearson	Upper Saddle River, NJ	www.pearson ed.com

Reasons for recommendation (include information on match to curriculum concepts and skills):

Recommended text is better organized and should facilitate student comprehension of science concepts. Text aligns well with science and engineering practices. On line resources are superior and will greatly enhance student experiences.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
300	Student Textbook	\$84.97	\$25491	150
150	Study Resource Book (Student Edition)	\$10.87	\$1630.50	75

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
10	Teachers Edition	\$106.47	\$1064.70	5
10	Study Workbook (Teacher Edition)	\$26.97	\$269.70	5
2	Exam View CD-ROM	\$138.47	\$276.94	1
10	Classroom Resource DVD-ROM	No charge	No Charge	5

TOTAL COST	
Total Cost for Student Texts/Materials	\$2,7121
Total Cost for Teacher Materials	\$1,611.34
GRAND TOTAL	\$28,732.34

Textbook Selection Committee		
Staff member	School	Grade/Course Taught
Kimberly Nettleton	BCHS	Env Sci ACA
John Couture	BCHS	Env Sci ACA
Elizabeth DiLernia	BEHS	Env Sci ACA



Textbook Recommendation to the Board of Education

Subject/Course: Business & Finance – Computer Programming and Video Game Design (CPVGD) **Grade Level:** 10-12

First Presentation BOE Meeting Date: June 4, 2014 - Request waiver of 2nd reading

Describe need for the textbook/materials: To build and strengthen students' literacy skills pursuant to CCSS and provide reading opportunities in the computer programming content area.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total	Readability
BUSINESS/ Computer Programming and Video Game Design	The Ultimate Guide to Video Game writing and Design	Flint Dille and John Zuur Platten	first	2007	Lone Eagle Press	45/54	11-12
	Games and Graphics in C++	Tony Gaddis	2nd	2010, 2014	Pearson	29/54	13-14

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
BUSINESS/ Computer Programming and Video Game Design	The Ultimate Guide to Video Game writing and Design	Flint Dille and John Zuur Platten	first	2007	Lone Eagle Press (Watson Guptill)	New York, NY	www.crownpublishing.com

Reasons for recommendation (include information on match to curriculum concepts and skills):

Recommended text tells the story of the video game industry and should provide an important framework for student work in this area. This text will support our goal to engage students with reading in the content area. The book is lightweight and portable – paperback.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
200	The Ultimate Guide to Video Game writing and Design	13.99	\$2,798.00	100

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
N/A				
N/A				
N/A				

TOTAL COST	
Total Cost for Student Texts/Materials	\$2,798.00
Total Cost for Teacher Materials	-0-
GRAND TOTAL	\$2,798.00

Textbook Selection Committee		
Staff member	School	Grade/Courses Taught
John Harris	BEHS	9-12 Business and Finance
Pat Branagan	BCHS	9-12 Business and Finance
Laurie Roberge	BCHS	9-12 Business and Finance
Sharon Jacques	BEHS	9-12 Business and Finance



Textbook Recommendation to the Board of Education

Subject/Course: French III

Grade Level: high school

First Presentation BOE Meeting Date: June 4, 2014 **Second Presentation BOE Meeting Date:** July 2, 2014

Describe need for the textbook/materials:

The French III curriculum was recently revised, and approved by the Board of Education's Student Achievement Committee, to provide more rigorous course work for students. The previous textbook has become outdated and no longer meets the demands to support the course.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Copyright Date	Publisher	Rubric Score Total	Readability
French III	D'accord	José A. Blanco	2011	Vista Higher Learning	41	Level 3
French III	Bon Voyage	J. Schmitt, Katia Brillié Lutz	2008	Glencoe	39	Level 3
French III	C'est à toi	Karla Winther Fawbush, Toni Thiesen, Dianne B. Hopen, Sarah Vaillancourt	2007	EMC	41	Level 3

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/ Course	Title of Book	Author(s)	Editi on	Copyri ght Date	Publisher	City, State Of Publisher	Publisher Website
French III	D'accord	Vista Higher Learning		2011	José A. Blanco	Boston, MA	www.vistahigherlearning.com

Reasons for recommendation (include information on match to curriculum concepts and skills):

See last page.

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
70	Level 3 Student Edition w/ Supersite code	\$108.00 978-1-60576-657-	\$7,560	40 BCHS, 30 BEHS

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
3	Complete teacher resource kit	\$333	\$0 (\$999 value gratis)	2 to BCHS
				1 to BEHS

TOTAL COST	
Total Cost for Student Texts/Materials	\$7,560
Total Cost for Teacher Materials	\$0 (\$999 value gratis)
Shipping & handling	\$599.13
GRAND TOTAL	\$8,159.13

Textbook Selection Committee		
Staff member	School	Grade/Course Taught
Anya Rochester	Bristol Central High School	French 9-12
Kelly Lynne Thibodeau	Bristol Eastern High School	French 9-12
Also, 6 French students		

French Textbook Selection

Present: Kelly Lynne Thibodeau, Anya Rochester; 6 French students

Materials used:

- 3 French texts
- Textbook evaluations
- Pacing/vocabulary comparison
- CT State Frameworks
- CT Common Core
- Bristol Power Standards
- Bristol Curriculum
- Notes from textbook presentations
- Student comments from textbook presentations
- Personal notes from textbook review
- National French Contest Specifications (by level) for 2012; this will help to maintain the rigor in our program and a competitive edge

What are we looking for in a textbook?

- Level-appropriate
- Finish each level in 1 year
- More rigor than prior years; the textbook needs more material and faster pacing
- Appropriate articulation of vocabulary, structures, and concepts; no “forced units.”
- We also want more of key structures, such as the past tense, to be introduced sooner than it is in the current curriculum and the textbook
- Meet district guidelines
- Book that appeals to students (We will use the student feedback)
- Up-to-date materials
- One book per year, per level

Initial/thoughts and comparisons

C'est à Toi (EMC)	D'accord (Vista)	Bon Voyage (Glencoe)
• We liked the paired practice and materials that are actually in the textbook; she liked how there were cartoons, and some of the personal prompts were suited to student needs • It seemed like the culture was not as appealing as the other books; it was “boring.” • There were not as many prompts that helped students to connect to their own culture • We have the Spanish version of this text,	• We all liked this book best. • Is the text too overwhelming visually? Is that why many of our students didn't like it? • We really liked the visuals – modern, lots of pictures – doesn't look too old. • We liked the videos, which used real videos, not just contrived situations (which are also there). • We really liked the structure of the book. • Is the material in this book too	• The representative told us that students will “learn all the grammar they need to know in the first two books.” This philosophy makes it seem like the grammar is overwhelming; there is too much, and it seems forced. • The books look old. • Most of the students found this book to be visually more appealing; although it had less online, the students found this text to be less overwhelming and more structured. They really liked that this

C'est à Toi (EMC)	D'accord (Vista)	Bon Voyage (Glencoe)
which Anya does not like. They have similar structures. • Etre is not in the first few chapters; it is later. We feel this is a critical item to come sooner. • We liked some of the other items that were introduced sooner. • The online resources are phenomenal, with amazing resources for contemporary culture. • The layout is "childish;" students found it to be not appealing. • It looks "skimpy" in terms of how things are shared. • The text in this (as compared to the Spanish text, which follows a similar structure), there is a disconnectedness to the materials. The units don't seem cohesive. • No level 4 book offered in this series, and no suggestions or books sold by the same publisher for level 4.	dense? • We like that the textbook is available online, as well as the videos; however – we would have to pay an additional fee for access to online workbooks, which there is not for "C'est à Toi." • The book is divided into manageable pieces. • There is a level four for this (a choice of two), but they are not officially in the series. • Anya did like the structure and pacing; she liked that être is at the beginning of the book. • What is taught in level 1 in this book is what we teach through level 3 in terms of grammatical concepts. • How much is the workbook for online access? How much is that paid? • What is the difference in price between the paper copy of the workbook and the online? • How complicated is the online stuff? • We really liked the units in level 3. • Vista has the least amount of ancillary materials.	textbook seemed to be a resource unto itself. • We really liked the assessments at the end of each chapter. • Foldables, tips, etc., very usable in the teacher edition. The book seems to have many resources. • They really liked the images. • We liked that in the teacher's edition, it tells that the books are structured to help to meet the needs of a variety of levels – half of the activities are "required" and half are extras. The extras are readings, and could be used to differentiate between ACA/ACC. • 14 chapters – very long! Would this put is in the same situation as now, where we don't accomplish the entire book in one year? • Has PowerPoint presentations already made. • Has Level 4 text that is different from the series, but one is offered.

Final decision:

Based on the CT frameworks, the articulation, the pacing, the focus on higher-order thinking, and authentic materials, the national standards, the district curriculum, the variety of materials, we choose **Vista's D'accord**.

Concerns/Questions about Vista:

1. What do the level 4 books look like? Will we want to purchase those? Anya is going to request copies of those.



COST PROPOSAL

Quote Prepared On Dec. 13, 2013

Quote Valid Through Feb 25, 2014

Payment Terms Net 30 Days

Quote No. 13112105

COST PROPOSAL

Prepared For

Keri Coombs
Bristol Public School District
129 Church Street
Bristol CT, 06010

Prepared By

Shannon DiStefano
sdistefano@vistahigherlearning.com
(800) 618-7375 ext. 9356
Vista Higher Learning
500 Boylston St, Suite 620
Boston, MA 02116-3736

Daccord 1e					
Qty	Item Number	Description	Unit Price	Total Value	Total Cost
3	978-1-60576-614-0	Daccord *L3 Teacher Resource Box	\$333.00	\$999.00	\$0.00
70	978-1-61767-940-7	Daccord L3 SE + SS + CA + CE	\$108.00	\$7,560.00	\$7,560.00

Total Value	\$8,559.00
Total Gratis	\$999.00
Total Cost	\$7,560.00
Est. Shipping (7%)	\$599.13
Est. Grand Total Cost	\$8,159.13

Special Instructions

Please include a copy of your signed and dated tax exemption certificate when sending in your purchase order.

To Order Contact Customer Service

Phone (800) 269-6311 ext. 1 | **Fax** (617) 426-5215

Email info@vistahigherlearning.com

Vista Higher Learning

500 Boylston St. Suite 620 Boston, MA 02116

Thank you for your business!



Textbook Recommendation to the Board of Education

Subject/Course: World Languages / Spanish IV

Grade Level: 10-12

First Presentation BOE Meeting Date: June 2, 2014

Second Presentation BOE Meeting Date: July 2, 2014

Describe need for the textbook/materials: Curriculum for the Spanish IV course was revised this spring, as part of the district's routine cycle of curriculum review. The revision created more rigorous expectations in preparing students to study Spanish at an accelerated and deeper level, which will better prepare them to become proficient and to study the language in college. A new textbook was needed to meet the demands of this revision.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Rubric Score Total	Readability	Publisher Website
World Languages / Spanish I	<i>Aventura 4</i>	Vargas Bonilla	Spanish	2009	EMC Publishing	St. Paul, MN	49/54	Appropriate for Level 4	educate@emcp.com
World Languages / Spanish I	<i>Avancemos 4</i>	Gahala, Hamilton-Garlin, Heining-Boynton, Otheguy, Rupert	Spanish	2010	Holt McDougal		39/54	Appropriate for Level 4	holtmcdougal.hmhco.com

The following textbook(s)/materials are recommended by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
World Languages / Spanish IV	<i>Aventura 4</i>	Vargas Bonilla	Spanish	2009	EMC Publishing	St. Paul, MN	educate@emcp.com

Student Materials Needed				
Qty 150	Item Name <i>Aventura 4 student edition</i> <i>Aventura 4 student workbook</i>	Cost /Item \$78.95 plus 10% S&H	Total Cost \$15,658.50	Distribution: BCHS 75 BEHS 75
			TOTAL COST	
	Total Cost for student materials		\$11,842.50	
	Total Cost for teacher materials (plus, student workbooks)		\$2,392.50	
	Shipping and Handling 10%		\$1,423.50	
	GRAND TOTAL			
			Textbook Selection Committee	
	Staff member		School	Grade/Course Taught
	Andrea Rajotte		Bristol Eastern High School	Spanish
	Debra Kempton		Bristol Eastern High School	Spanish
	Norma Torres		Bristol Eastern High School	Spanish
	Edwin Garcia		Bristol Central High School	Spanish
	Kathleen Archibald		Bristol Central High School	Spanish
	Frances Nickeson		Bristol Central High School	Spanish

Reasons for recommendation (include information on match to curriculum concepts and skills):

Vargas Bonilla's textbook, entitled *Aventura 4*, is recommended for the following reasons:

- Provides greater rigor, consistent with teachers' and district's goal of preparing students to develop proficiency and study Spanish in college
- Embeds rich and relevant cultural references
- Unfolds learning objectives in a way that allows students to reinforce and build upon learning from unit to unit
- Provides plenty of opportunities and materials for students to practice skills
- Offers robust ancillary material, with a wealth of interactive on-line material to help student to listen, speak and write as a Spanish speaker

Textbook Recommendation to the Board of Education

TEXTBOOK REVIEW BY STANDARDS

TEXTBOOK TITLE: Glencoe Math Course 1

Standards in 6 th Grade Mathematics Curriculum		Evidence Demonstrated (Section)
Ratios and Proportional Relationships		
<i>A. Understand Ratio concepts and use ratio reasoning to solve problems.</i>		
6.RP.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. <i>For example, "The ratio of wings to beaks in the bird house at the zoo was 2:1, because for every 2 wings there was 1 beak." "For every vote candidate A received, candidate C received nearly three votes."</i>	1.2
6.RP.2	Understand the concept of a unit rate a/b associated with a ratio $a:b$ with $b \neq 0$, and use rate language in the context of a ratio relationship. <i>For example, "This recipe has a ratio of 3 cups of flour to 4 cups of sugar, so there is $3/4$ cup of flour for each cup of sugar." "We paid \$75 for 15 hamburgers, which is a rate of \$5 per hamburger." (Expectations for unit rates in this grade are limited to non-complex fractions.)</i>	1.3
6.RP.3	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.	1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 2.6, 2.7, 2.8, 4.5, 7.4
	a. Make tables of equivalent ratios relating quantities with whole number measurements, find missing values in the tables, and plot the pairs of values on the coordinate plane. Use tables to compare ratios.	1.4, 1.5
	b. Solve unit rate problems including those involving unit pricing and constant speed. <i>For example, if it took 7 hours to mow 4 lawns, then at that rate, how many lawns could be mowed in 35 hours? At what rate were lawns being mowed?</i>	1.3, 1.4, 1.6, 1.7
	c. Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means $30/100$ times the quantity); solve problems involving finding the whole, given a part and the percent.	2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8
	d. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.	4.5
The Number System		
<i>B. Apply and extend previous understanding of multiplication and division to divide fractions by fractions.</i>		
6.NS.1	Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions, e.g., by using visual fraction models and equations to represent the problem. <i>For example, create a story context for $(2/3) \div (3/4)$ and use a visual fraction model to show the quotient; use the relationship between multiplication and division to explain that $(2/3) \div (3/4) = 8/9$ because $3/4$ of $8/9$ is $2/3$. (In general, $(a/b) \div (c/d) = ad/bc$.) How much chocolate will each person get if 3 people share $1/2$ lb of</i>	4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.8

	<i>chocolate equally? How many $\frac{3}{4}$-cup servings are in $\frac{2}{3}$ of a cup of yogurt? How wide is a rectangular strip of land with length $\frac{3}{4}$ mi and area $\frac{1}{2}$ square mi?</i>	
	C. Compute fluently with multi-digit numbers and find common factors and multiples.	
6.NS.2	Fluently divide multi-digit numbers using the standard algorithm.	3.5, 3.6
6.NS.3	Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.	3.1, 3.2, 3.3, 3.4, 3.7, 3.8, 6.1
6.NS.4	Find the greatest common factor of two whole numbers less than or equal to 100 and the least common multiple of two whole numbers less than or equal to 12. Use the distributive property to express a sum of two whole numbers 1–100 with a common factor as a multiple of a sum of two whole numbers with no common factor. <i>For example, express $36 + 8$ as $4(9 + 2)$.</i>	1.1, 6.6
	D. Apply and extend previous understandings of numbers to the system of rational numbers.	
6.NS.5	Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.	5.1
6.NS.6	Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.	5.1, 5.2, 5.5, 5.6, 5.7
	a. Recognize opposite signs of numbers as indicating locations on opposite sides of 0 on the number line; recognize that the opposite of the opposite of a number is the number itself, e.g., $-(-3) = 3$, and that 0 is its own opposite.	5.1, 5.2
	b. Understand signs of numbers in ordered pairs as indicating locations in quadrants of the coordinate plane; recognize that when two ordered pairs differ only by signs, the locations of the points are related by reflections across one or both axes.	5.6, 5.7
	c. Find and position integers and other rational numbers on a horizontal or vertical number line diagram; find and position pairs of integers and other rational numbers on a coordinate plane.	5.1, 5.4, 5.5, 5.6, 5.7
6.NS.7	Understand ordering and absolute value of rational numbers.	5.2, 5.3, 5.5
	a. Interpret statements of inequality as statements about the relative position of two numbers on a number line diagram. <i>For example, interpret $-3 > -7$ as a statement that -3 is located to the right of -7 on a number line oriented from left to right.</i>	5.3, 5.4, 5.5
	b. Write, interpret, and explain statements of order for rational numbers in real-world contexts. <i>For example, write $-3^{\circ}\text{C} > -7^{\circ}\text{C}$ to express the fact that -3°C is warmer than -7°C.</i>	5.3
	c. Understand the absolute value of a rational number as its distance from 0 on the number line; interpret absolute value as	5.2

	magnitude for a positive or negative quantity in a real-world situation. <i>For example, for an account balance of -30 dollars, write $-30 = 30$ to describe the size of the debt in dollars.</i>	
	d. Distinguish comparisons of absolute value from statements about order. <i>For example, recognize that an account balance less than -30 dollars represents a debt greater than 30 dollars.</i>	5.2, 5.3
6.NS.8	Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.	5.7, 9.5
Expressions and Equations		
<i>E. Apply and extend previous understanding of arithmetic to algebraic expressions.</i>		
6.EE.1	Write and evaluate numerical expressions involving whole-number exponents.	6.1, 6.2
6.EE.2	Write, read, and evaluate expressions in which letters stand for numbers.	6.2, 6.4, 6.7, 8.1, 8.2
	a. Write expressions that record operations with numbers and with letters standing for numbers. <i>For example, express the calculation "Subtract y from 5" as $5 - y$.</i>	6.4
	b. Identify parts of an expression using mathematical terms (sum, term, product, factor, quotient, coefficient); view one or more parts of an expression as a single entity. <i>For example, describe the expression $2(8 + 7)$ as a product of two factors; view $(8 + 7)$ as both a single entity and a sum of two terms.</i>	6.7
	c. Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations). <i>For example, use the formulas $V = s^3$ and $A = 6s^2$ to find the volume and surface area of a cube with sides of length $s = 1/2$.</i>	6.3, 6.4, 8.1, 8.2
6.EE.3	Apply the properties of operations to generate equivalent expressions. <i>For example, apply the distributive property to the expression $3(2 + x)$ to produce the equivalent expression $6 + 3x$; apply the distributive property to the expression $24x + 18y$ to produce the equivalent expression $6(4x + 3y)$; apply properties of operations to $y + y + y$ to produce the equivalent expression $3y$.</i>	6.5, 6.6, 6.7
6.EE.4	Identify when two expressions are equivalent (i.e., when the two expressions name the same number regardless of which value is substituted into them). <i>For example, the expressions $y + y + y$ and $3y$ are equivalent because they name the same number regardless of which number y stands for.</i>	6.7
<i>F. Reason about and solve one-variable equations and inequalities.</i>		
6.EE.5	Understand solving an equation or inequality as a process of answering a question: which values from a specified set, if any, make the equation or inequality true? Use substitution to determine whether a given number in a specified set makes an	7.1, 7.2, 7.3, 7.4, 7.5, 8.5, 8.7

	equation or inequality true.	
6.EE.6	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.	6.3, 6.4, 8.2, 8.6, 8.7
6.EE.7	Solve real-world and mathematical problems by writing and solving equations of the form $x + p = q$ and $px = q$ for cases in which p , q and x are all nonnegative rational numbers.	7.2, 7.3, 7.4, 7.5
6.EE.8	Write an inequality of the form $x > c$ or $x < c$ to represent a constraint or condition in a real-world or mathematical problem. Recognize that inequalities of the form $x > c$ or $x < c$ have infinitely many solutions; represent solutions of such inequalities on number line diagrams.	8.5, 8.6, 8.7
G. Represent and analyze quantitative relationships between dependent and independent variables.		
6.EE.9	Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. <i>For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation $d = 65t$ to represent the relationship between distance and time.</i>	8.1, 8.2, 8.3, 8.4
Geometry		
H. Solve real-world and mathematical problems involving area, surface area, and volume.		
6.G.1	Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes; apply these techniques in the context of solving real-world and mathematical problems.	9.1, 9.2, 9.3, 9.4, 9.5, 9.6
6.G.2	Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying the edge lengths of the prism. Apply the formulas $V = lwh$ and $V = bh$ to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.	10.1, 10.2
6.G.3	Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate. Apply these techniques in the context of solving real-world and mathematical problems	9.5
6.G.4	Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems.	10.3, 10.4, 10.5

Statistics and Probability		
<i>I. Develop understanding of statistical variability.</i>		
6.SP.1	Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. <i>For example, “How old am I?” is not a statistical question, but “How old are the students in my school?” is a statistical question because one anticipates variability in students’ ages.</i>	
6.SP.2	Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.	12.3, 12.4
6.SP.3	Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.	11.1, 11.2, 11.3
<i>K. Summarize and describe distributions.</i>		
P.4	Display numerical data in plots on a number line, including dot plots, histograms, and box plots.	12.1, 12.2, 12.4, 12.5, 12.6
6.SP.5	Summarize numerical data sets in relation to their context, such as by:	11.2, 11.3, 11.4, 11.5, 12.1, 12.2, 12.3, 12.4
	a. Reporting the number of observations.	12.1, 12.2
	b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.	11.2, 11.4, 12.1, 12.2, 12.3
	c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.	11.2, 11.3, 11.4, 11.5, 12.1, 12.3
	d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.	11.5, 12.4

TEXTBOOK REVIEW BY STANDARDS

TEXTBOOK TITLE: Glencoe Math Course 2

Standards in 7 th Grade Mathematics Curriculum		Evidence Demonstrated (Section)
Ratios and Proportional Relationships <i>A. Analyze proportional relationships and use them to solve real-world and mathematical problems.</i>		
7.RP.1	Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. <i>For example, if a person walks $\frac{1}{2}$ mile in each $\frac{1}{4}$ hour, compute the unit rate as the complex fraction $\frac{1/2}{1/4}$ miles per hour, equivalently 2 miles per hour.</i>	1.2
7.RP.2	Recognize and represent proportional relationships between quantities.	1.1, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9
	a. Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.	1.4, 1.5, 1.9
	b. Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.	1.1, 1.4, 1.6, 1.7, 1.8, 1.9
	c. Represent proportional relationships by equations. <i>For example, if total cost t is proportional to the number n of items purchased at a constant price p, the relationship between the total cost and the number of items can be expressed as $t = pn$.</i>	1.6, 2.4
	d. Explain what a point (x, y) on the graph of a proportional relationship means in terms of the situation, with special attention to the points $(0, 0)$ and $(1, r)$ where r is the unit rate.	1.7
7.RP.3	Use proportional relationships to solve multistep ratio and percent problems. <i>Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.</i>	1.3, 1.6, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 4.7
The Number System <i>B. Apply and extend previous understanding of operations with fractions to add, subtract, multiply, and divide rational numbers.</i>		
7.NS.1	Apply and extend previous understandings of addition and subtraction to add and subtract rational numbers; represent addition and subtraction on a horizontal or vertical number line diagram.	3.2, 3.3, 4.3, 4.4, 4.5
	a. Describe situations in which opposite quantities combine to make 0. <i>For example, a hydrogen atom has 0 charge because its two constituents are oppositely charged.</i>	3.2
	b. Understand $p + q$ as the number located a distance $ q $ from p , in the positive or negative direction depending on whether q is positive or negative. Show that a number and its opposite have a sum of 0 (are additive inverses). Interpret sums of rational	3.2

	numbers by describing real-world contexts.	
	c. Understand subtraction of rational numbers as adding the additive inverse, $p - q = p + (-q)$. Show that the distance between two rational numbers on the number line is the absolute value of their difference, and apply this principle in real-world contexts.	3.3, 4.3
	d. Apply properties of operations as strategies to add and subtract rational numbers.	3.2, 3.3, 4.3, 4.4, 4.5
7.NS.2	Apply and extend previous understandings of multiplication and division and of fractions to multiply and divide rational numbers.	3.4, 4.1, 4.2, 4.6, 4.7, 4.8
	a. Understand that multiplication is extended from fractions to rational numbers by requiring that operations continue to satisfy the properties of operations, particularly the distributive property, leading to products such as $(-1)(-1) = 1$ and the rules for multiplying signed numbers. Interpret products of rational numbers by describing real-world contexts.	3.4, 4.6
	b. Understand that integers can be divided, provided that the divisor is not zero, and every quotient of integers (with non-zero divisor) is a rational number. If p and q are integers, then $-(p/q) = (-p)/q = p/(-q)$. Interpret quotients of rational numbers by describing real world contexts.	4.2
	c. Apply properties of operations as strategies to multiply and divide rational numbers.	3.4, 4.6, 4.8
	d. Convert a rational number to a decimal using long division; know that the decimal form of a rational number terminates in 0s or eventually repeats.	4.1
7.NS.3	Solve real-world and mathematical problems involving the four operations with rational numbers. (Computations with rational numbers extend the rules for manipulating fractions to complex fractions.)	1.2, 3.1, 3.2, 3.3, 3.4, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8
Expressions and Equations		
<i>C. Use properties of operations to generate equivalent expressions</i>		
7.EE.1	Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.	5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8
7.EE.2	Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. <i>For example, $a + 0.05a = 1.05a$ means that “increase by 5%” is the same as “multiply by 1.05.”</i>	2.6, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8
<i>D. Solve real-life and mathematical problems using numerical and algebraic expressions and equations.</i>		
7.EE.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. <i>For example: If a woman making \$25 an hour gets a 10% raise, she will make an additional 1/10 of her</i>	2.1, 2.2, 2.4, 2.5, 2.6, 2.7, 2.8, 3.2, 3.4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8

	<i>salary an hour, or \$2.50, for a new salary of \$27.50. If you want to place a towel bar $9\frac{3}{4}$ inches long in the center of a door that is $27\frac{1}{2}$ inches wide, you will need to place the bar about 9 inches from each edge; this estimate can be used as a check on the exact computation.</i>	
7.EE.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.	6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8
	a. Solve word problems leading to equations of the form $px + q = r$ and $p(x + q) = r$, where p , q , and r are specific rational numbers. Solve equations of these forms fluently. Compare an algebraic solution to an arithmetic solution, identifying the sequence of the operations used in each approach. <i>For example, the perimeter of a rectangle is 54 cm. Its length is 6 cm. What is its width?</i>	6.1, 6.2, 6.3, 6.4, 6.5
	b. Solve word problems leading to inequalities of the form $px + q > r$ or $px + q < r$, where p , q , and r are specific rational numbers. Graph the solution set of the inequality and interpret it in the context of the problem. <i>For example: As a salesperson, you are paid \$50 per week plus \$3 per sale. This week you want your pay to be at least \$100. Write an inequality for the number of sales you need to make, and describe the solutions.</i>	6.6, 6.7, 6.8
Geometry <i>E. Draw, construct, and describe geometrical figures and describe the relationships between them.</i>		
7.G.1	Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.	7.4
7.G.2	Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.	7.3
7.G.3	Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.	7.5, 7.6
<i>F. Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.</i>		
7.G.4	Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.	8.1, 8.2, 8.3
7.G.5	Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure.	7.1, 7.2
7.G.6	Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.	8.3, 8.4, 8.5, 8.6, 8.7, 8.8
Statistics and Probability		

G. Use random sampling to draw inferences about a population.		
7.SP.1	Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.	10.1, 10.2, 10.3, 10.5
7.SP.2	Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. <i>For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction might be.</i>	10.1, 10.2
H. Draw informal comparative inferences about two populations.		
7.SP.3	Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. <i>For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.</i>	
7.SP.4	Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations. <i>For example, decide whether the words in a chapter of a seventh-grade science book are generally longer than the words in a chapter of a fourth-grade science book.</i>	10.4
I. Investigate chance processes and develop, use, and evaluate probability models.		
7.SP.5	Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.	9.1, 9.5
7.SP.6	Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability. <i>For example, when rolling a number cube 600 times, predict that a 3 or 6 would be rolled roughly 200 times, but probably not exactly 200 times.</i>	
7.SP.7	Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.	9.1, 9.2
	a. Develop a uniform probability model by assigning equal probability to all outcomes, and use the model to determine	9.1, 9.2

	probabilities of events. <i>For example, if a student is selected at random from a class, find the probability that Jane will be selected and the probability that a girl will be selected.</i>	
	b. Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process. <i>For example, find the approximate probability that a spinning penny will land heads up or that a tossed paper cup will land open-end down. Do the outcomes for the spinning penny appear to be equally likely based on the observed frequencies?</i>	9.2
7.SP.8	Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.	9.3, 9.4, 9.5, 9.6, 9.7
	a. Understand that, just as with simple events, the probability of a compound event is the fraction of outcomes in the sample space for which the compound event occurs.	9.3, 9.5, 9.6, 9.7
	b. Represent sample spaces for compound events using methods such as organized lists, tables and tree diagrams. For an event described in everyday language (e.g., “rolling double sixes”), identify the outcomes in the sample space which compose the event.	9.3, 9.5, 9.7
	c. Design and use a simulation to generate frequencies for compound events. <i>. For example, use random digits as a simulation tool to approximate the answer to the question: If 40% of donors have type A blood, what is the probability that it will take at least 4 donors to find one with type A blood?</i>	9.4

TEXTBOOK REVIEW BY STANDARDS

TEXTBOOK TITLE: Glencoe Math – Bridge to Algebra

Standards in 7 th Grade Bridge to Algebra Mathematics Curriculum		Evidence Demonstrated (Section)
Rational Numbers and Exponents <i>A. Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.</i>		
7.NS.1	Apply and extend previous understandings of addition and subtraction to add and subtract rational numbers; represent addition and subtraction on a horizontal or vertical number line diagram.	2.1, 2.2, 2.3, 3.1, 3.5, 3.6
	a. Describe situations in which opposite quantities combine to make 0. <i>For example, a hydrogen atom has 0 charge because its two constituents are oppositely charged.</i>	2.1, 2.2
	b. Understand $p + q$ as the number located a distance $ q $ from p , in the positive or negative direction depending on whether q is positive or negative. Show that a number and its opposite have a sum of 0 (are additive inverses). Interpret sums of rational numbers by describing real-world contexts.	2.2
	c. Understand subtraction of rational numbers as adding the additive inverse, $p - q = p + (-q)$. Show that the distance between two rational numbers on the number line is the absolute value of their difference, and apply this principle in real-world contexts.	2.3
	d. Apply properties of operations as strategies to add and subtract rational numbers.	2.3, 2.3, 3.5, 3.6
7.NS.2	Apply and extend previous understandings of multiplication and division and of fractions to multiply and divide rational numbers.	2.4, 2.5, 3.1, 3.2, 3.3, 3.4, 7.1
	a. Understand that multiplication is extended from fractions to rational numbers by requiring that operations continue to satisfy the properties of operations, particularly the distributive property, leading to products such as $(-1)(-1) = 1$ and the rules for multiplying signed numbers. Interpret products of rational numbers by describing real-world contexts.	2.4, 3.3, 3.4
	b. Understand that integers can be divided, provided that the divisor is not zero, and every quotient of integers (with non-zero divisor) is a rational number. If p and q are integers, then $-(p/q) = (-p)/q = p/(-q)$. Interpret quotients of rational numbers by describing real world contexts.	2.5
	c. Apply properties of operations as strategies to multiply and divide rational numbers.	2.4, 2.5, 3.3, 3.4, 7.1
	d. Convert a rational number to a decimal using long division; know that the decimal form of a rational number terminates in 0s or eventually repeats.	3.1, 3.2
7.NS.3	Solve real-world and mathematical problems involving the four operations with rational numbers. (Computations with rational	1.1, 1.2, 1.3, 1.5, 2.2, 2.3,

	numbers extend the rules for manipulating fractions to complex fractions.)	2.4, 2.5, 3.3, 3.4, 3.5, 3.6, 5.3
B. Know that there are numbers that are not rational, and approximate them by rational numbers.		
8.NS.1	Know that numbers that are not rational are called irrational. Understand informally that every number has a decimal expansion; for rational numbers show that the decimal expansion repeats eventually, and convert a decimal expansion which repeats eventually into a rational number.	3.1, 3.2, 4.7
8.NS.2	Use rational approximations of irrational numbers to compare the size of irrational numbers, locate them approximately on a number line diagram, and estimate the value of expressions (e.g., π^2). <i>For example, by truncating the decimal expansion of $\sqrt{2}$, show that $\sqrt{2}$ is between 1 and 2, then between 1.4 and 1.5, and explain how to continue on to get better approximations.</i>	4.6, 4.7
C. Work with radicals and integer exponents		
8.EE.1	Know and apply the properties of integer exponents to generate equivalent numerical expressions. <i>For example, $3^2 \times 3^{-5} = 3^{-3} = 1/3^3 = 1/27$.</i>	4.1, 4.2, 4.3, 4.4, 4.5
8.EE.2	Use square root and cube root symbols to represent solutions to equations of the form $x^2 = p$ and $x^3 = p$, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that $\sqrt{2}$ is irrational.	4.6, 4.7
8.EE.3	Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. <i>For example, estimate the population of the United States as 3×10^8 and the population of the world as 7×10^9, and determine that the world population is more than 20 times larger.</i>	4.4, 4.5
8.EE.4	Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology.	4.4, 4.5
Proportionality and Linear Relationships		
D. Analyze proportional relationships and use them to solve real-world and mathematical problems.		
7.RP.1	Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. <i>For example, if a person walks $1/2$ mile in each $1/4$ hour, compute the unit rate as the complex fraction $1/2 \div 1/4$ miles per hour, equivalently 2 miles per hour.</i>	5.1, 5.2, 5.3, 5.4
7.RP.2	Recognize and represent proportional relationships between quantities.	1.6, 2.6, 5.5, 5.6, 5.7, 5.9, 5.10, 6.1, 6.3, 9.4
	a. Decide whether two quantities are in a proportional	1.6, 2.6, 5.5, 5.6, 9.4

	relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.	
	b. Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.	1.6, 2.6, 5.5, 5.6, 5.7, 9.3, 9.4
	c. Represent proportional relationships by equations. <i>For example, if total cost t is proportional to the number n of items purchased at a constant price p, the relationship between the total cost and the number of items can be expressed as $t = pn$.</i>	5.5, 5.7, 5.9, 5.10, 6.1, 6.3, 9.3
	d. Explain what a point (x, y) on the graph of a proportional relationship means in terms of the situation, with special attention to the points $(0, 0)$ and $(1, r)$ where r is the unit rate.	1.6, 2.6, 5.6, 9.3
7.RP.3	Use proportional relationships to solve multistep ratio and percent problems. <i>Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.</i>	1.6, 2.6, 5.6, 9.3
E. Use properties of operations to generate equivalent expressions.		
7.EE.1	Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.	1.4, 7.1, 7.2, 7.3, 7.4, 7.5
7.EE.2	Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. <i>For example, $a + 0.05a = 1.05a$ means that “increase by 5%” is the same as “multiply by 1.05.”</i>	1.4, 6.4, 6.5, 7.1, 7.2
F. Solve real-life and mathematical problems using numerical and algebraic expressions and equations.		
7.EE.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. <i>For example: If a woman making \$25 an hour gets a 10% raise, she will make an additional $\frac{1}{10}$ of her salary an hour, or \$2.50, for a new salary of \$27.50. If you want to place a towel bar $9\frac{3}{4}$ inches long in the center of a door that is $27\frac{1}{2}$ inches wide, you will need to place the bar about 9 inches from each edge; this estimate can be used as a check on the exact computation.</i>	1.1, 1.5, 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 6.1, 6.2, 6.3, 6.4, 6.5
7.EE.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.	1.3, 1.7, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 9.1, 9.2, 9.5
	a. Solve word problems leading to equations of the form $px + q = r$ and $p(x + q) = r$, where p , q , and r are specific rational numbers. Solve equations of these forms fluently. Compare an algebraic solution to an arithmetic solution, identifying the sequence of the operations used in each approach. <i>For example, the perimeter of a rectangle is 54 cm. Its length is 6 cm. What is its</i>	8.2, 8.3, 8.4, 8.5, 8.8

	<i>width?</i>	
	b. Solve word problems leading to inequalities of the form $px + q > r$ or $px + q < r$, where p , q , and r are specific rational numbers. Graph the solution set of the inequality and interpret it in the context of the problem. <i>For example: As a salesperson, you are paid \$50 per week plus \$3 per sale. This week you want your pay to be at least \$100. Write an inequality for the number of sales you need to make, and describe the solutions.</i>	8.7, 8.8
	G. Understand the connections between proportional relationships, lines, and linear equations.	
8.EE.5	Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. <i>For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.</i>	1.6, 2.6, 5.6, 9.3, 9.4
8.EE.6	Use similar triangles to explain why the slope m is the same between any two distinct points on a non-vertical line in the coordinate plane; derive the equation $y = mx$ for a line through the origin and the equation $y = mx + b$ for a line intercepting the vertical axis at b .	
	H. Analyze and solve linear equations and pairs of simultaneous linear equations	
8.EE.7	Solve linear equations in one variable.	8.1, 8.2, 8.3, 8.4, 8.5, 8.8
	a. Give examples of linear equations in one variable with one solution, infinitely many solutions, or no solutions. Show which of these possibilities is the case by successively transforming the given equation into simpler forms, until an equivalent equation of the form $x = a$, $a = a$, or $a = b$ results (where a and b are different numbers).	8.8
	b. Solve linear equations with rational number coefficients, including equations whose solutions require expanding expressions using the distributive property and collecting like terms.	8.1, 8.2, 8.3, 8.4, 8.5, 8.8
	Introduction to Sampling and Inference	
	I. Use random sampling to draw inferences about a population.	
7.SP.1	Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.	10.5
7.SP.2	Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. <i>For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction</i>	10.5

	<i>might be.</i>	
	J. Draw informal comparative inferences about two populations.	
7.SP.3	Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. <i>For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.</i>	
7.SP.4	Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations. <i>For example, decide whether the words in a chapter of a seventh-grade science book are generally longer than the words in a chapter of a fourth-grade science book.</i>	10.1, 10.2, 10.3, 10.4
	K. Investigate chance processes and develop, use, and evaluate probability models.	
7.SP.5	Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.	10.6
7.SP.6	Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability. <i>For example, when rolling a number cube 600 times, predict that a 3 or 6 would be rolled roughly 200 times, but probably not exactly 200 times.</i>	
7.SP.7	Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.	10.7
	a. Develop a uniform probability model by assigning equal probability to all outcomes, and use the model to determine probabilities of events. <i>For example, if a student is selected at random from a class, find the probability that Jane will be selected and the probability that a girl will be selected.</i>	10.7
	b. Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process. <i>For example, find the approximate probability that a spinning penny will land heads up or that a tossed paper cup will land open-end down. Do the outcomes for the spinning penny appear to be equally likely based on the observed frequencies?</i>	10.7
7.SP.8	Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.	10.8
	a. Understand that, just as with simple events, the probability of a compound event is the fraction of outcomes in the sample	10.8

	space for which the compound event occurs.	
	b. Represent sample spaces for compound events using methods such as organized lists, tables and tree diagrams. For an event described in everyday language (e.g., “rolling double sixes”), identify the outcomes in the sample space which compose the event.	10.8
	c. Design and use a simulation to generate frequencies for compound events. <i>For example, use random digits as a simulation tool to approximate the answer to the question: If 40% of donors have type A blood, what is the probability that it will take at least 4 donors to find one with type A blood?</i>	
Creating, Comparing, and Analyzing Geometric Figures		
<i>L. Draw, construct, and describe geometrical figures and describe the relationships between them.</i>		
7.G.1	Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.	5.8
7.G.2	Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.	
7.G.3	Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.	12.4
<i>M. Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.</i>		
7.G.4	Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.	12.1, 12.2, 12.9
7.G.5	Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure.	11.1
7.G.6	Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.	12.3, 12.5, 12.8, 12.10
N. Understand congruence and similarity using physical models, transparencies, or geometry software.		
8.G.1	Verify experimentally the properties of rotations, reflections, and translations:	
	a. Lines are taken to lines, and line segments to line segments of the same length.	
	b. Angles are taken to angles of the same measure.	
	c. Parallel lines are taken to parallel lines.	
8.G.2	Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent	11.6

	figures, describe a sequence that exhibits the congruence between them.	
8.G.3	Describe the effect of dilations, translations, rotations, and reflections on two-dimensional figures using coordinates.	11.4, 11.5, 11.7
8.G.4	Understand that a two-dimensional figure is similar to another if the second can be obtained from the first by a sequence of rotations, reflections, translations, and dilations; given two similar two-dimensional figures, describe a sequence that exhibits the similarity between them.	11.8
8.G.5	Use informal arguments to establish facts about the angle sum and exterior angle of triangles, about the angles created when parallel lines are cut by a transversal, and the angle-angle criterion for similarity of triangles. <i>For example, arrange three copies of the same triangle so that the sum of the three angles appears to form a line, and give an argument in terms of transversals why this is so.</i>	11.1, 11.2, 11.3
O. Solve real-world and mathematical problem involving volume of cylinders, cones, and spheres.		
8.G.9	Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.	12.6, 12.7

TEXTBOOK REVIEW BY STANDARDS

TEXTBOOK TITLE: Glencoe Math -Course 3

Standards in 8 th Grade Mathematics Curriculum		Evidence Demonstrated (Section)
The Number System <i>A. Know that there are numbers that are not rational, and approximate them by rational numbers.</i>		
8.NS.1	Know that numbers that are not rational are called irrational. Understand informally that every number has a decimal expansion; for rational numbers show that the decimal expansion repeats eventually, and convert a decimal expansion which repeats eventually into a rational number.	1.1, 1.10
8.NS.2	Use rational approximations of irrational numbers to compare the size of irrational numbers, locate them approximately on a number line diagram, and estimate the value of expressions (e.g., π^2). <i>For example, by truncating the decimal expansion of $\sqrt{2}$, show that $\sqrt{2}$ is between 1 and 2, then between 1.4 and 1.5, and explain how to continue on to get better approximations.</i>	1.9, 1.10
Expression and Equations <i>B. Work with radicals and integer exponents.</i>		
8.EE.1	Know and apply the properties of integer exponents to generate equivalent numerical expressions. <i>For example, $3^2 \times 3^{-5} = 3^{-3} = 1/3^3 = 1/27$.</i>	1.2, 1.3, 1.4, 1.5
8.EE.2	Use square root and cube root symbols to represent solutions to equations of the form $x^2 = p$ and $x^3 = p$, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that $\sqrt{2}$ is irrational.	1.8, 1.9, 1.10, 5.5, 5.6, 5.7
8.EE.3	Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. <i>For example, estimate the population of the United States as 3×10^8 and the population of the world as 7×10^9, and determine that the world population is more than 20 times larger.</i>	1.7
8.EE.4	Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology.	1.6, 1.7
<i>C. Understand the connections between proportional relationships, lines, and linear equation.</i>		
8.EE.5	Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. <i>For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.</i>	3.1, 3.2, 3.3
8.EE.6	Use similar triangles to explain why the slope m is the same	3.3, 3.4, 7.6

	between any two distinct points on a non-vertical line in the coordinate plane; derive the equation $y = mx$ for a line through the origin and the equation $y = mx + b$ for a line intercepting the vertical axis at b .	
D. Analyze and solve linear equations and pairs of simultaneous linear equations.		
8.EE.7	Solve linear equations in one variable.	2.1, 2.2, 2.3, 2.4, 2.5
	a. Give examples of linear equations in one variable with one solution, infinitely many solutions, or no solutions. Show which of these possibilities is the case by successively transforming the given equation into simpler forms, until an equivalent equation of the form $x = a$, $a = a$, or $a = b$ results (where a and b are different numbers).	2.1, 2.2, 2.3, 2.4, 2.5
	b. Solve linear equations with rational number coefficients, including equations whose solutions require expanding expressions using the distributive property and collecting like terms.	2.1, 2.2, 2.3, 2.4, 2.5
8.EE.8	Analyze and solve pairs of simultaneous linear equations.	3.7, 3.8
	a. Understand that solutions to a system of two linear equations in two variables correspond to points of intersection of their graphs, because points of intersection satisfy both equations simultaneously.	3.7
	b. Solve systems of two linear equations in two variables algebraically, and estimate solutions by graphing the equations. Solve simple cases by inspection. <i>For example, $3x + 2y = 5$ and $3x + 2y = 6$ have no solution because $3x + 2y$ cannot simultaneously be 5 and 6.</i>	3.7, 3.8
	c. Solve real-world and mathematical problems leading to two linear equations in two variables. <i>For example, given coordinates for two pairs of points, determine whether the line through the first pair of points intersects the line through the second pair.</i>	3.5, 3.6, 3.7, 3.8
Functions		
E. Define, evaluate, and compare functions.		
8.F.1	Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. (Function notation is not required in Grade 8.)	4.2, 4.3, 4.4, 4.7
8.F.2	Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). <i>For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change.</i>	3.3, 4.5,
8.F.3	Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. <i>For example, the function $A = s^2$ giving the area of a</i>	3.4, 4.4, 4.7, 4.8

	<i>square as a function of its side length is not linear because its graph contains the points (1,1), (2,4) and (3,9), which are not on a straight line.</i>	
F. Use functions to model relationships between quantities.		
8.F.4	Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.	3.3, 3.4, 4.1, 4.3, 4.4, 4.5, 4.6
8.F.5	Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.	4.7, 4.8, 4.9
Geometry		
G. Understand congruence and similarity using physical models, transparencies, or geometry software.		
8.G.1	Verify experimentally the properties of rotations, reflections, and translations:	6.1, 6.2, 6.3, 7.1
	a. Lines are taken to lines, and line segments to line segments of the same length.	7.1
	b. Angles are taken to angles of the same measure.	7.1
	c. Parallel lines are taken to parallel lines.	
8.G.2	Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent figures, describe a sequence that exhibits the congruence between them.	7.1, 7.2
8.G.3	Describe the effect of dilations, translations, rotations, and reflections on two-dimensional figures using coordinates.	6.1, 6.2, 6.3, 6.4
8.G.4	Understand that a two-dimensional figure is similar to another if the second can be obtained from the first by a sequence of rotations, reflections, translations, and dilations; given two similar two-dimensional figures, describe a sequence that exhibits the similarity between them.	7.3, 7.4, 7.7
8.G.5	Use informal arguments to establish facts about the angle sum and exterior angle of triangles, about the angles created when parallel lines are cut by a transversal, and the angle-angle criterion for similarity of triangles. <i>For example, arrange three copies of the same triangle so that the sum of the three angles appears to form a line, and give an argument in terms of transversals why this is so.</i>	5.1, 5.3, 5.4, 7.5
H. Understand and apply the Pythagorean Theorem.		
8.G.6	Explain a proof of the Pythagorean Theorem and its converse.	5.2
8.G.7	Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.	5.5, 5.6

8.G.8	Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.	8.1, 8.2, 8.3, 8.4, 8.5, 8.6
<i>I. Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.</i>		
8.G.9	Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.	8.1, 8.2, 8.3, 8.4, 8.5, 8.6
Statistics and Probability		
<i>J. Investigate patterns of association in bivariate data.</i>		
8.SP.1	Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.	9.1, 9.2
8.SP.2	Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.	9.2
8.SP.3	Use the equation of a linear model to solve problems in the context of bivariate measurement data, interpreting the slope and intercept. <i>For example, in a linear model for a biology experiment, interpret a slope of 1.5 cm/hr as meaning that an additional hour of sunlight each day is associated with an additional 1.5 cm in mature plant height.</i>	9.2
8.SP.4	Understand that patterns of association can also be seen in bivariate categorical data by displaying frequencies and relative frequencies in a two-way table. Construct and interpret a two-way table summarizing data on two categorical variables collected from the same subjects. Use relative frequencies calculated for rows or columns to describe possible association between the two variables. <i>For example, collect data from students in your class on whether or not they have a curfew on school nights and whether or not they have assigned chores at home. Is there evidence that those who have a curfew also tend to have chores?</i>	9.3



Textbook Recommendation to the Board of Education

Subject/Course: Middle School Mathematics

Grade Level: 6 - 8

First Presentation BOE Meeting Date: June 4, 2014

Second Presentation BOE Meeting Date: July 2, 2014

Describe need for the textbook/materials: Two years ago, Bristol Public Schools adopted a middle school curriculum aligned to the Common Core State Standards. In support of that adoption, it is recommended to purchase a common set of instructional materials to meet the revised curriculum standards.

Listed below are textbooks/materials evaluated by the Textbook Selection Committee:

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	Rubric Score Total	Readability
Math Grade 6-8	Go Math 2015	Kanold, Larson, Leinwand	1st	2014	Houghton Mifflin Harcourt	40	
Math Grade 6-8	Carnegie Learning	Bartle, Meyer	1st	2011	Carnegie Learning	28.6	
Math Grade 6-8	Glencoe Common Core Edition 2015	Carter, Cuevas, Day, Malloy, Kersaint, Reynosa, Sibley, Vielhaber	1st	2015	McGraw Hill Education	43.1	800-880

The following textbook(s)/materials are recommended by the Textbook Selection Committee

Subject/ Course	Title of Book	Author(s)	Edition	Copyright Date	Publisher	City, State Of Publisher	Publisher Website
Math Grade 6-8	Glencoe Math: Built to the Common Core CCSS 2015	Carter, Cuevas, Day, Malloy, Kersaint, Reynosa, Sibley, Vielhaber	1st	2015	McGraw Hill Education	Bothell, WA Chicago, IL Columbus, OH New York, NY	https://www.mheonline.com/program/view/2/16/2853/GLNMATH015/

Reasons for recommendation (include information on match to curriculum concepts and skills): see attached document

Textbook Recommendation to the Board of Education

Student Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: #Texts per School
654	Glencoe Math Course 1 Student Bundle – Grade 6	\$74.97	\$49,030.38	GH-104, WB-98, CHMS-271, NE-150
441	Glencoe Math Course 2 Student Bundle – Grade 7	\$74.97	\$33,061.77	GH-64, WB-84, CHMS-190, NE-82
130	Glencoe Math Accelerated Student Bundle – Bridge to Algebra Grade 7	\$74.97	\$9,746.10	GH-18, WB-19, CHMS-49, NE-44
517	Glencoe Math Course 3 Student Bundle – Grade 8	\$74.97	\$38,759.49	GH-73, WB-75, CHMS-238, NE-106

Teacher Materials Needed				
Quantity	Item Name	Cost Per Item	Total Cost	Distribution: # per School
11	Glencoe Math Course 1 Vol. 1 & 2 Teacher Edition	Free	Free	GH-2, WB-2, CHMS-4, NE-3
11	Glencoe Math Course 2 Vol. 1 & 2 Teacher Edition	Free	Free	GH-2, WB-2, CHMS-4, NE-3
7	Glencoe Math Accelerated Vol. 1 & 2 Teacher Ed.	Free	Free	GH-1, WB-1, CHMS-3, NE-2
10	Glencoe Math Course 3 Vol. 1 & 2 Teacher Edition	Free	Free	GH-2, WB-2, CHMS-3, NE-3

TOTAL COST	
Total Cost for Student Texts/Materials	\$130,597.74 + \$6084.59 for shipping and handling
Total Cost for Teacher Materials	free
GRAND TOTAL	\$136, 682.33

Textbook Selection Committee		
Staff member	School	Grade/Course Taught
Susan Sirois	Northeast	Grade 6/7 math
Elizabeth Lafferty	Northeast	Grade 8 math
Sharon Dixon	West Bristol	Grade 6
Kyle Phelan	West Bristol	Grade 7
Sue Martel	West Bristol	Grade 8
Mariliz Fitzpatrick	Chippens Hill	Grade 6
John Dauphinee	Chippens Hill	Grade 6
Gina Rivera	Chippens Hill	Grade 7
Reinhard Walker	Chippens Hill	Grade 8
Jennifer Michalek	Chippens Hill	Grade 8
Karen Mancuso	Greene-Hills	Grade 6
Sarah Lupa	Greene-Hills	Grade 7
Cheryl Caron	Greene-Hills	Grade 8