AP Physics C
College Board AP Audit Information

Primary Textbook: Paul A. Tipler, Physics for Scientists and Engineers, 4th ed., W. H. Freeman and Company, 1999.

Course Description: The AP Physics C course consists of:

1. Newtonian mechanics.
2. Electricity and magnetism.

Conceptual understanding of these topics and problem solving will be emphasized. Algebra and trigonometry are the primary mathematical skills needed in the course, although calculus will be used when necessary. This course is not just for high achievers or students with natural ability; hard-working students with an interest in physics will find success in this course.

Course Evaluation: In keeping with school district policy, the nine weeks grade will be determined as follows:

1. 50% daily work (homework, labs, and readings).
2. 40% exams.
3. 10% final exam.

Exams will be modeled after the AP exam and will contain multiple choice and free response questions from College Board released exams.

Laboratory Experiences: Students will participate in at least one laboratory exercise per topic of study, when appropriate. The high school has a mobile cart on wheels with six laptop computers and the necessary software and hardware to perform real-time data collection. Laboratory exercises from Physics with Computers, Physical Science with Computers, Real-Time Physics, and Tools for Scientific Thinking are used for real-time data collection. Students also complete standard laboratory exercises to collect data with traditional measurement instruments. Where appropriate, lab activities are extended to allow students to manipulate variables of their own choosing to satisfy the "what if" and "how about" questions they pose as a consequence of the lab activity. Every student submits his or her own laboratory report. Students come in before or after school or during lunch to complete laboratory exercises should they fall behind. The laboratory component of the course is operationally defined following the course syllabus in a section entitled Laboratory Investigations and Goals.

Homework: Homework is a combination of problems assigned from the textbook and chosen from the University of Texas at Austin Homework Service. Textbook problems are completed in their entirety, with students showing all their work, and submitted for grading. Textbook problems are selected from those listed in each topic, but do not include every problem listed. The UT Homework Service problems consist of a mixture of old AP multiple-choice questions, problems from the Tipler physics text, and problems from the Serway physics text. Students submit the UT homework online and are provided with seven opportunities to correct an incorrect answer. Students receive immediate feedback when submitting homework answers online.

The magazine articles come from Scientific American magazine, Discover magazine, and Popular Mechanics magazine.

Tutoring: I am available in the mornings from 8:00 to 8:45 a.m., at lunch, and until 5 p.m. after school (unless I have a prior commitment). Students can find my e-mail address in the instructions on every UT homework assignment and on the school website. Students receive help through e-mail in the evenings, over weekends, and over holiday periods.

Additional Resources:

1. The Mechanical Universe, Annenberg Media Video On Demand (www.learner.org). A series of videotape programs covering the basic topics of an introductory physics course.
2. Physics Education Technology Group Simulations, University of Colorado (phet.colorado.edu). Interactive simulations of physical phenomena in which students are allowed to manipulate variable and observe the corresponding effect on the system in question.
3. Halliday, David, Robert Resnick, and Jearl Walker. Fundamentals of Physics, 6th ed. New York: John Wiley & Sons, 2001.
4. Chabay, Ruth, and Bruce Sherwood. Electric and Magnetic Interactions, 1st ed. New York: John Wiley & Sons, 1995. Also: Electric and Magnetic Interactions: The Movies, Ruth Chabay, North Carolina State University (www4.ncsu.edu/%7Erwchabay/emimovies).
5. Young, Hugh D., Roger A. Freedman, T. R. Sandin, and A. Lewis Ford. Sears and Zemansky's University Physics, 10th ed. Reading, MA: Addison-Wesley, 2000.
6. Knight, Randall D. Physics for Scientists and Engineers: A Strategic Approach. New York: Pearson Education, 2004.
7. Serway, Ramond A., and John Jewett. Principles of Physics, 3rd ed. Willard, OH: Thomson Learning, 2002.
8. Kleppner, Daniel, and Norman Ramsey. Quick Calculus: A Self-Teaching Guide, 2nd ed. New York: John Wiley & Sons, 1985.

9. MIT OpenCourseWare, Massachusetts Institute of Technology (ocw.mit.edu/index.html). Web-based electronic publishing initiative that provides access to MIT's course materials for teachers, students.
10. HyperPhysics, Georgia Southern University (hyperphysics.phy-astr.gsu.edu/hbase/hframe.html). An exploration environment for concepts in physics which employs concept maps. Provides opportunities for numerical exploration in the form of active formulae and standard problems.
11. Advanced Placement Digital Library, Rice University (http://adpl.rice.edu/). A collection of Internet resources that have been reviewed for their educational merit in an AP or Pre-AP classroom.

Course Syllabus

1. Vectors: students will learn about vector addition, vector subtraction, components of vectors, rectangular resolution of vectors, and the component and parallelogram method for determining the resultant of two or more concurrent vectors.
   a. Read Chapter 3, Sections 1 & 2, pp. 54 – 59; Ch. 6 Section 2, pp. 155 – 157; Ch. 10, Section 1, pp. 296 – 297.
   b. Lab: Physics Education Technology (PhET) Vector Simulation (phet.colorado.edu).
   c. UT homework: 01.
   d. Tipler homework: Ch. 3, pp. 75 – 76, #5, 6, 7, 8, 9, 10, 14, 15, 16, 17, 18, 19, 20
   e. Tipler homework: Ch. 6, p. 172, #23, 25, 26, 28.
   f. Tipler homework: Ch. 10, p. 313, #5, 6, 8, 9..
   g. Exam: vectors.
2. One-Dimensional Kinematics: students will learn about displacement, average and instantaneous velocity, average and instantaneous acceleration, constant acceleration and the kinematics equations for constant acceleration, and vertical gravitational acceleration and free fall motion. Students will construct and interpret position – time graphs, velocity – time graphs, and acceleration – time graphs. Students will also learn about limits and derivatives.
   a. Read Chapter 2 Sections 1, 2, 3, pp. 19 - 38.
   b. Labs:
      i. Changing Motion.
      ii. Graphical Analysis of Motion – Uniformly Accelerated Motion.
   c. UT homework: 02.
   d. Tipler homework: Ch. 2, pp. 44 - 48, #4, 7, 12, 14, 17, 19, 20, 21, 26, 28, 36, 39, 40, 57, 61. 66, 72. 73, 78.
   e. Exam: one-dimensional kinematics.
3. Two-Dimensional Kinematics: students will learn about the characteristics of motion in two dimensions and the strategies for solving problems involving projectiles fired horizontally and at an angle. Students will also learn about limits and derivatives.
   a. Read Chapter 3 Sections 3 & 4, pp. 59 – 72.
   b. Labs:
      i. Motion of a Projectile.
      ii. PhET Projectile Motion simulation.
   c. UT homework 03.
   d. Tipler homework: Ch. 3, pp. 76 - 81, #25, 32, 33, 37, 39, 42, 47, 50, 55, 58, 64, 69, 70, 76, 102.
   e. Exam: two-dimensional kinematics.

4. Newton's Laws of Motion: students will learn about contact and field forces; balanced and unbalanced forces; the concept of inertia; the relationship between force, mass, and acceleration; Newton's third law; mass and weight; the tension force; the normal force and frictional forces on horizontal and inclined surfaces; the conditions and forces involved in static equilibrium conditions; the characteristics of uniform circular motion; centripetal acceleration; centripetal force as a net force on horizontal and inclined surfaces and in vertical circles; and drag forces.
    a. Read Chapter 4 Sections 1 - 7, pp. 83 - 102; Chapter 5 Sections 1 - 3, pp. 114 - 136.
    b. Labs:
        i. Terminal Velocity and Air Resistance.
        ii. Newton's Second Law: The Atwood Machine.
        iii. Force, Mass, and Acceleration.
        iv. Friction.
        v. Centripetal Force.
    c. UT homework: 04 – Newton's laws; 05 –friction and centripetal force.
    d. Tipler homework: Ch. 4, pp. 105 – 112; #16, 31, 32, 33, 41, 45, 47, 49, 51, 55, 56, 65, 69, 78, 81, 95.
    e. Tipler homework: Ch. 5, pp. 139 – 146, #9,, 12, 15, 17, 18, 21, 23, 28, 38, 49, 53, 58, 60, 70, 73, 76, 81, 85.
    f. Exam: Newton's Laws.
5. Work and Energy: students learn about the work done by a constant force; estimating the work done by a varying force; conservative and nonconservative forces; energy as the ability to do work; elastic potential energy, gravitational potential energy, and kinetic energy; the work – energy theorem and its problem-solving applications; the law of conservation of energy and its problem-solving applications; and mechanical power. Students will learn about integration.
    a. Read Ch 6 Sections 1 - 4, pp. 148 – 168; Ch. 7 Sections 1 & 2, pp. 178 - 194.
    b. Labs:
        i. Conservation of Potential Energy.
        ii. Work, Energy, and Friction.
    c. UT homework: 06 – work and power; 07 – energy.
    d. Tipler homework: Ch. 6, pp. 171 – 176, #7, 10, 13, 14, 20, 36, 42, 46, 61, 68, 85, 86, 89.
    e. Tipler homework: Ch. 7, pp. 203 – 210, #6, 8, 9, 10, 12, 14, 17, 21, 25, 29, 47, 49, 51, 74, 80, 89, 95.
    f. Exam: work and energy.

6. Momentum: students learn about impulse and changes in linear momentum; elastic and inelastic collisions in one and two dimensions and their problem-solving applications; and determining the center of mass.
    a. Read Ch. 8 Sections 1 - 6, pp. 212 - 238.
    b. Labs:
        i. Conservation of Momentum: Internal Force.
        ii. Conservation of Momentum: A Collision in Two Dimensions.
        iii. Impulse and Momentum.
        iv. Ballistic Pendulum.
    c. UT homework: 08 – center of gravity; 09 – momentum.
    d. Tipler homework: Ch. 8, pp. 246 – 253, #5, 7, 9 14, 19, 33, 35, 45, 49, 60, 69, 72, 112.
    e. Exam: momentum.
7. Rotational Kinematics: students learn about angular velocity, angular acceleration, the torque about an axis, torque and equilibrium situations, the moment of inertia and means of calculating the value of I, applications of $\tau = I \cdot \alpha$ for rotation, and rotational kinetic energy and its problem solving applications.
    a. Read Ch. 9 Sections 1 - 6, pp. 257 - 291.
    b. Labs:
        i. Center of Gravity and Equilibrium.
        ii. Moments of Inertia.
    c. UT homework: 10.
    d. Tipler homework: Ch. 9, pp. 284 – 291, #5, 6, 7, 10, 15, 23, 24, 29, 33, 34, 35, 50, 54, 57, 60, 68, 73.
    e. Exam: rotational kinematics.
8. Conservation of Angular Momentum: students learn about the vector nature of rotation, angular momentum, torque and angular momentum, and conservation of angular momentum.
    a. Read Ch. 10 Sections 1 – 4, pp. 295 – 309.
    b. Lab: Ballistic Pendulum: Conservation of Angular Momentum and Energy.
    c. UT homework: 11.
    d. Tipler homework: Ch. 10, pp. 313 – 319, #15, 23, 36, 38, 49, 52, 53, 67, and 77.
    e. Tipler homework: Ch. 9, pp. 267 – 270, #6, 8, 17, 23, 27, 31, 36, 37, and 38.
    f. Exam: conservation of angular momentum.
9. Gravity: students learn about Kepler's laws, Newton's Law of Universal Gravitation, gravitational potential energy, the gravitational field, and problem solving applications for Kepler's laws and the Law of Universal Gravitation.
    a. Read Ch. 11 Sections 1 – 4, pp. 321 – 337; The Big G magazine article; Weightlessness magazine article.

   b. Labs:
      i. Gravitational Forces.
      ii. Gravitational Acceleration of a Projectile.
   c. UT homework: 12.
   d. Tipler homework: Ch. 11, pp. 334 - 350, #12, 13, 18, 20, 23, 41, 43, 49, 55, 61, 94, 105.
   e. Exam: gravitation.

10. Oscillations: students learn about the kinematics of simple harmonic motion, the energy changes in simple harmonic motion, oscillating systems, damped oscillations, and driven oscillations and resonance.
    a. Read Ch. 14 Sections 1 - 5, pp. 403 - 427.
    b. Labs:
       i. Hooke's Law and Simple Harmonic Motion.
       ii. The Simple Pendulum.
       iii. Elasticity and Energy Transformations.
    c. UT homework: 13.
    d. Tipler homework: Ch. 14, pp. 433 - 440, #6, 7, 9, 10, 13, 15, 21, 22, 44, 53, 102, 107.
    e. Exam: oscillations.

**C1 Course Requirement: Electrostatics**

11. Electric Charge and Electric Field: students learn about electric charge, conductors and insulators, Coulomb's law and its problem solving applications, the electric field and electric field lines, the electric fields produced by various charge distributions and their problem solving applications, and electric dipoles and their problem solving applications.
    a. Read Ch. 22 Sections 1 – 7, pp. 657 - 678.
    b. Labs:
        i. Coulomb's Law.
        ii. Electrostatic Effects.
        iii. Mapping of Electric Fields.
        iv. PhET Electric Charge and Electric Field Simulation.
    c. MIT OpenCourseWare Electrostatics visualizations: (http://ocw.mit.edu/OcwWeb/Physics/8-02TSpring-2005/Visualizations/detail/electrostatics.htm)
    d. UT homework: 13 – electric charge; 14 – electric fields.
    e. Tipler homework: Ch. 22, pp. 681 – 686, #9, 13, 19, 25, 26, 29, 38, 45, 49, 54, 80, 90.
    f. Exam: electric charge and electric fields.
12. Electric Fields (Gauss's Law): students learn about electric flux and its problem solving applications, and Gauss's law and its problem solving applications.
    a. Read Ch. 23 Sections 1 – 3, pp. 688 – 706, pp. 707 – 710.
    b. Electric and Magnetic Interactions: The Movies, Ruth Chabay, North Carolina State University ( http://www4.ncsu.edu/%7Erwchabay/emimovies/)
    c. UT homework: 15.
    d. Tipler homework: Ch. 23, pp. 713 – 717, #2, 4, 6, 8, 23, 24, 31, 33, 34, 55, 59.
    e. Exam: Gauss's law.
13. Electric Potential: students learn about electric potential energy, electric potential, the electric potential for various charge distributions and their problem solving applications, equipotential surfaces, and determining the electric field from the electric potential.
    a. Read Ch. 24 Sections 1 – 5, pp. .
    b. UT homework: 16.
    c. Tipler homework: Ch. 24, pp. 745 – 750, #5, 11, 15, 23, 27, 31, 37, 39, 42, 48, 61, 67, 86, 92.
    d. Exam: electric potential.

**C2 Course Requirement: Conductors, Capacitors, and Dielectrics**

14. Capacitors and Dielectrics: Students learn about capacitance, the determination of capacitance for various geometric shapes, the storage of electric energy, capacitors in series, capacitors in parallel, combinations of capacitors, and dielectric materials.
    a. Read Ch. 25 Sections 1 – 5, pp. 752 - 771.
    b. Lab: Charging and Discharging a Capacitor.
    c. UT homework: 17.
    d. Tipler homework: Ch. 25, pp. 777 – 784, #5, 23, 33, 35, 37, 42, 53, 56, 64, 67, 88, 102, 104.
    e. Exam: capacitance.

**C3 Course Requirement: Electric Circuits**

15. Electric Current and DC Circuits: students learn about current, drift velocity, the factors affecting resistance, Ohm's law, energy in electric circuits, resistors in series and parallel and in combination, Kirchhoff's rules, and RC circuits.
    a. Read Ch. 26 Sections 1 – 6, pp. 786 – 815.
    b. Labs:
        i. Ohm's Law.
        ii. Resistances in Series and Parallel
        iii. Voltage Division in an Electrical Circuit.
        iv. Multiloop Circuits: Kirchhoff's Rules.
        v. RC Circuit Lab.
    c. UT homework: 18.
    d. Tipler homework: Ch. 26, pp. 818 – 825, #6, 8, 25, 26, 31, 59, 60, 83, 86, 90, 114, 116, 117, 118.
    e. Exam: DC circuits.

**C4 Course Requirement: Magnetic Fields**

16. Magnetic Fields: students learn about the force exerted on moving charges by a magnetic field, the magnetic force of current carrying wires, magnetic field lines, the motion of point charges in a magnetic field (cyclotron period and frequency, velocity selectors, and mass spectrometers), and the torque on current loops and magnets.
    a. Read Ch. 28 Sections 1 & 2, pp. 855 – 867.
    b. Labs:
        i. Magnetic Fields Around Magnets.
        ii. Strength of a Magnetic Field.
        iii. Magnetic Effect of a Current.
    c. MIT OpenCourseWare Magnetostatics visualizations: (http://ocw.mit.edu/OcwWeb/Physics/8-02TSpring-2005/Visualizations/detail/magnetostatics.htm)
    d. Electric and Magnetic Interactions: The Movies, Ruth Chabay, North Carolina State University (http://www4.ncsu.edu/%7Erwchabay/emimovies/)
    e. UT homework: 19.
    f. Tipler homework: Ch. 28, pp. 877 – 882, #4, 5, 7, 9, 13, 22, 26, 29, 86, 89.
    g. Exam: magnetic fields.
17. Sources of the Magnetic Field: students learn about the magnetic field of a moving point charge, the magnetic field of a current (Biot-Savart law applied to a solenoid, a current loop, and straight conductor), Gauss's law for magnetism, and Ampere's law.
    a. Read Ch. 29 Sections 1 – 4, pp. 883 – 901.

b. Lab:
    i. Magnetic Field of a Slinky.
c. UT homework: 20.
d. Tipler homework: Ch. 29, pp. 918 – 924, # 8, 13, 16, 24, 26, 29, 31, 37, 40, 46, 52, 53, 54, 99.
e. Exam: sources of magnetic fields.

**C5 Course Requirement: Electromagnetism**

18. Magnetic Induction: students learn about magnetic flux, induced EMF and Faraday's law, Lenz's law, motional EMF, self and mutual inductance, the energy stored in an inductor, and RL circuits.
    a. Read Ch. 30 Sections 1 – 4, 6, & 8, pp. 927 – 938, pp. 939 – 942, and pp. 944 – 947; Ch. 31 Section 5, pp. 969 – 972.
    b. Labs:
        i. Induced Current and Lenz's Law.
        ii. Electromagnetic Induction.
        iii. RL Circuit Lab.
        iv. PhET Faraday's EM Lab.
        v. PhET Faraday's Law simulation.
    c. MIT OpenCourseWare Faraday's Laws visualizations: (http://ocw.mit.edu/OcwWeb/Physics/8-02TSpring-2005/Visualizations/detail/faraday.htm)
    d. UT homework: 21.
    e. Tipler homework: Ch. 30, pp. 952 – 957, # 9, 10, 12, 14, 15, 18, 21, 25, 33, 64, 66, 72, 74, 75.
    f. Tipler homework: Ch. 31, p. 993, #26, and 28.
    g. Exam: magnetic induction.
19. Maxwell's Equations and EM Waves: students learn about displacement current and Maxwell's equations.
    a. Read Ch. 32 Sections 1 & 2, pp. 999 – 1003.
    b. Lab: PhET Radio Waves and Electromagnetic Fields simulation (http://phet.colorado.edu/)
    c. UT homework: 22.
    d. Tipler homework: Ch. 32, pp. 1021 – 1022, #1, 3, 5.

AP Physics C
College Board AP Audit Information
Laboratory Investigations and Goals

Laboratory Experiences: Students will participate in at least one laboratory exercise per topic of study, when appropriate or possible. The high school has a mobile cart on wheels with six laptop computers and the necessary software and hardware to perform real-time data collection. Laboratory exercises from Physics with Computers, Physical Science with Computers, Real-Time Physics, and Tools for Scientific Thinking are used for real-time data collection. Students also complete standard laboratory exercises to collect data with traditional measurement instruments. Class time is used to collect data and analysis is completed by students prior to the next class meeting. Where appropriate, lab activities are extended to allow students to manipulate variables of their own choosing to satisfy the "what if" and "how about" questions they pose as a consequence of the lab activity. Every student submits his or her own laboratory report. Students come in before or after school or during lunch to complete laboratory exercises should they fall behind.

Syllabus

20. Vectors:
    - i. Physics Education Technology (PhET) Vector Addition Simulation (http://phet.colorado.edu): virtual.
        1. Students assemble vectors in any manner they wish and can view the x and y components of each vector, the angles the vectors make with the x-axis, and the vector sum of the assembled vectors.
        2. Completion time: 30 minutes.
21. One-Dimensional Kinematics:
    - i. Changing Motion: student conducted.
        1. Students use a motion detector and carts to examine/graph/interpret the displacement, velocity, and acceleration of a moving object.
    - ii. Graphical Analysis of Motion – Uniformly Accelerated Motion: student conducted.
        1. Students measure the motion of a cart down an incline at various angles and analyze the distance traveled over time to determine/graph the speed and acceleration of the cart.
        2. Completion time: 45 minutes.
22. Two-Dimensional Kinematics:
    - i. Projectile Motion Lab: student conducted.
        1. Students determine the velocity of a horizontally launched projectile and then launch the projectile at 30°, 45°, and 60° degree angles to determine the velocity components, the time in the air, and the range (actual and predicted) for the projectiles.
        2. Completion time: 1 hour.
    - ii. PhET Projectile Motion simulation (http://phet.colorado.edu): virtual.
        1. Students can vary the type of projectile, the launch angle, the mass and the diameter of the projectile to determine the effect on the height and range of the projectile. Information can be obtained with and without air resistance.

2. Completion time: 30 minutes.

23. Newton's Laws of Motion:
    i. Terminal Velocity and Air Resistance: student conducted.
        1. Students use coffee filters and motion detectors to determine the terminal velocity of a falling object and the drag coefficient on the coffee filter.
        2. Completion time: 45 minutes.
    ii. Newton's Second Law: The Atwood Machine: student conducted.
        1. Students use an Atwood pulley apparatus and masses to examine how the acceleration of a system varies with changes in net force, changes in the mass of the system, and how the acceleration of the system can be determined mathematically.
        2. Completion time: 45 minutes.

- iii. Force, Mass, and Acceleration: student conducted
  1. Students vary the accelerating force on a cart and the mass of a cart to evaluate the effect on the acceleration of the cart.
  2. Completion time: 45 minutes.
- iv. Friction: student conducted.
  1. Students vary the angle and nature of the surface and measure the force required to pull a mass up and down the incline at constant speed to evaluate the coefficient of friction between the surfaces.
  2. Completion time: 45 minutes.
- v. Centripetal Force: student conducted.
  1. Students vary the rotating mass, the hanging mass, the radius of rotation, and the velocity to evaluate the relationship between centripetal force, mass, radius, and velocity.
  2. Completion time: 45 minutes.

24. Work and Energy:
- i. Conservation of Potential Energy: student conducted.
  1. Students use a spring and various masses to determine the elastic constant of the spring and the stored potential energy in the spring.
  2. Completion time: 45 minutes.
- ii. Work, Energy, and Friction: student conducted.
  1. Students vary the angle and nature of the surface and measure the force required to pull a mass up and down the incline at constant speed to evaluate the coefficient of friction between the surfaces.
  2. Completion time: 45 minutes.

25. Momentum:
- i. Conservation of Momentum: Internal Force: student conducted.
  1. Students will use spring-loaded carts moving in opposite directions to evaluate Newton's third law of motion and conservation of momentum.
  2. Completion time: 30 minutes.
- ii. Conservation of Momentum: A Collision in Two Dimensions: student conducted.
  1. Students use balls of the same and differing mass to observe and make measurements of the collision of two masses for the purpose of examining the momentum and energy relationships involved in a two dimensional elastic collision.
  2. Completion time: 45 minutes.
- iii. Impulse and Momentum: student conducted.

1. Students use a spring-loaded dynamics cart and masses to determine the spring constant of the spring and then attach timing tape to the cart to examine the relationship between impulse and momentum.
2. Completion time: 45 minutes.

iv. Ballistic Pendulum: student conducted.

1. Students measure the height to which a ballistic pendulum rises and use conservation of momentum to determine the potential energy and kinetic energy of the system and evaluate the ratio of the energy after to the energy before the collision.
2. Completion time: 30 minutes.

26. Rotational Kinematics:

i. Center of Gravity and Equilibrium: student conducted.

1. Students use a meterstick balance and masses to examine the relationship between the amount of mass and the position of the mass from the pivot point in order to establish equilibrium.
2. Completion time: 45 minutes.

ii. Moments of Inertia: student conducted.

1. Students will use a rotational inertia apparatus and masses to experimentally determine the moment of inertia of a body about an axis.
2. Completion time: 45 minutes.

27. Conservation of Angular Momentum:

i. Ballistic Pendulum: Conservation of Angular Momentum and Energy: student conducted.

1. Students will analyze the data collected in the Ballistic Pendulum lab and the free motion of the pendulum in terms of angular momentum and rotational kinetic energy to determine the initial velocity of the projectile.
2. Completion time: 40 minutes.

28. Gravity:

i. Gravitational Forces: student conducted.

1. Students will use a motion detector to measure the velocity and acceleration of a falling object.
2. Completion time: 45 minutes.

ii. Gravitational Acceleration of a Projectile: student conducted.

1. Students horizontally fire a projectile across an inclined plane at varying angles to evaluate the effect of the parallel component of gravity on the motion of the projectile.

2. Completion time: 45 minutes.

29. Oscillations:
    i. Hooke's Law and Simple Harmonic Motion: student conducted.
        1. Students will use springs, rubber bands, and various masses to determine the spring constant and examine how the period of oscillation varies with the mass and the spring constant.
        2. Completion time: 1 hour.
    ii. The Simple Pendulum: student conducted
        1. Students construct a simple pendulum and examine the relationship between pendulum lengths, amplitude of displacement, and mass on the period of the pendulum.
        2. Completion time: 45 minutes.
    iii. Elasticity and Energy Transformations: student conducted.
        1. Students use slotted masses and various springs and rubber bands, alone and in combination, to compare the elastic properties of different materials and to examine the energy transformations in a vibrating elastic object.
        2. Completion time: 1 hour.
30. Electric Charge and Electric Field:
    i. Coulomb's Law: student conducted.
        1. Students measure the mass of two charged spheres and the angle between them when suspended and apply Coulomb's law to determine the charge on each sphere.
        2. Completion time: 45 minutes.
    ii. Electrostatic Effects: student conducted.
        1. Students use pith balls, an electroscope, and a friction rod kit to observe the behavior of charged objects.
        2. Completion time: 45 minutes.
    iii. Mapping of Electric Fields: student conducted.
        1. Students use a field mapping board, with probes and conducting paper, to examine the nature of an electric field by mapping equipotential lines and drawing lines of force.
        2. Completion time: 1 hour.
    iv. PhET Electric Charge and Electric Field Simulation (http://phet.colorado.edu): virtual.
        1. Students manipulate charges to set up electric fields and observe the effect of the resultant electric field on test charges placed in the field.
        2. Completion time: 45 minutes.

31. Electric Fields (Gauss's Law):
32. Capacitors and Dielectrics:
    i. Charging and Discharging a Capacitor: student conducted.
        1. Students measure the rate of current flow into and out of a capacitor and mathematically and graphically determine the amount of charge stored in the capacitor, including capacitors in series and capacitors in parallel.
        2. Completion time: 45 minutes.
33. Electric Current and DC Circuits:
    i. Ohm's Law: student conducted.
        1. Students use an ammeter and a voltmeter to determine the resistance of common resistors (from Radio Shack).
        2. Completion time: 45 minutes.
    ii. Resistances in Series and Parallel: student conducted.
        1. Students use an ammeter and voltmeter to measure the effect of resistors in series and parallel on the current and potential difference in series circuits, parallel circuits, and a simple network. Students also use a voltmeter to examine the distribution of potential differences in a circuit.
        2. Completion time: 1 hour.

   iii. Multiloop Circuits: Kirchhoff's Rules: student conducted.
      1. Students use an ammeter and voltmeter and a circuit consisting of multiple resistors and voltage sources in two and three loops to measure the voltage and current at various points and apply Kirchhoff's rules to verify the measured current.
      2. Completion time: 1 hour.
   iv. RC Circuit Lab: student conducted.
      1. Students use resistors, capacitors, and an electric circuit to examine the RC time constant and what it means in terms of circuit characteristics and to illustrate how a capacitor charges and discharges through a resistor as a function of time.
      2. Completion time: 45 minutes.

34. Magnetic Fields:
   i. Magnetic Fields around Magnets: student conducted.
      1. Students use a compasses, a bar magnet, iron filings, and an electric circuit to examine the magnetic field surrounding a current-carrying wire.
      2. Completion time: 45 minutes.
   ii. Strength of a Magnetic Field: student conducted.
      1. Students will use an air core solenoid and a current balance in a circuit to measure/graph the relationship between the magnetic induction of a solenoid and the current in the solenoid.
      2. Completion time: 1 hour.
   iii. Magnetic Effect of a Current: student conducted.
      1. Students use a coil of wire, a compass, and an electric circuit to examine the relationship between the magnetic field strength at the center of the coil and the current passing through the coil.
      2. Completion time: 45 minutes.

35. Sources of the Magnetic Field:
   i. Magnetic Field of a Slinky: student conducted.
      1. Students use a slinky as a solenoid in an electric circuit to determine: the relationship between the magnetic field and current in a solenoid; the relationship between the magnetic field and the number of turns per meter in a solenoid; how the field varies inside and outside a solenoid; the value of the permeability constant $\mu_o$.
      2. Completion time: 45 minutes.

36. Magnetic Induction:
   i. Induced Current and Lenz's Law: student conducted.

1. Students will use coils of wire, bar magnets, a galvanometer connected in a circuit to examine Lenz's law and the factors affecting the strength of an induced current.
2. Completion time: 45 minutes.

ii. Electromagnetic Induction: student conducted.

1. Students use a primary-secondary coil set, magnets, metal rods, and an electric circuit to examine the relationship between magnetic flux and induced current.
2. Completion time: 45 minutes.

iii. RL Circuit Lab: student conducted.

1. Students use resistors, inductors, and an electric circuit to examine the RL time constant and what it means in terms of circuit characteristics.
2. Completion time: 45 minutes.

iv. PhET Faraday's EM Lab and PhET Faraday's Law simulation (http://phet.colorado.edu): virtual.

1. Students can manipulate a bar magnet through coils of wire and view the magnetic field lines and the induced current. Students can also manipulate variables related to electromagnets, generators, and transformers to see the effect on the resultant AC and DC current.
2. Completion time: 30 minutes.

37. Maxwell's Equations and EM Waves:

i. PhET Radio Waves and Electromagnetic Fields simulation (http://phet.colorado.edu): virtual.

1. Students manipulate transmitter electrons to view the wave and vector field characteristics of the electromagnetic field generated by the oscillating electron.
2. Completion time: 20 minutes.