AP Physics B
College Board AP Audit Information

Primary Textbook: Giancoli, Douglas C. Physics: Principles with Applications, 5th ed. Upper Saddle River, N.J.: Prentice Hall, 1998.

Course Description: The AP Physics B course consists of five general topics of study:

1. Newtonian mechanics.
2. Fluid mechanics and thermal physics.
3. Electricity and magnetism.
4. Waves and optics.
5. Atomic and nuclear physics.

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 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 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. Students also complete laboratory exercises modeled after the AP laboratory exam questions. Students are provided with the objective and equipment and decide what data needs to be collected, how to collect this data with the equipment available (or anything else lying around), how to organize and display the data, and how to analyze the data to obtain results from which conclusions can be derived. Students evaluate the effectiveness of their procedures and the quality of their data (data analysis).

The laboratory environment is an important factor for students to derive the greatest benefit from the lab activity. Students are encouraged to adjust their learning environment to enable learning; discussions within and between lab groups is encouraged.
Every student submits a laboratory report detailing the problem or question under investigation, hypotheses, the experimental methodology, data and observations, graphs and tables, calculations or statistics, and conclusions. Students are encouraged to retain their laboratory work as a portfolio of laboratory experiences should the college of their choice wish to observe their work.

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 variables 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. 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.
5. Knight, Randall D. Physics for Scientists and Engineers: A Strategic Approach. New York: Pearson Education, 2004.
6. Serway, Ramond A., and John Jewett. Principles of Physics, 3rd ed. Willard, OH: Thomson Learning, 2002.
7. Bloomfield, Louis A. How Things Work: The Physics of Everyday Life. New York: John Wiley & Sons, 1997.
8. 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.
9. Advanced Placement Digital Library, Rice University (adpl.rice.edu). A collection of Internet resources that have been reviewed for their educational merit in an AP or Pre-AP classroom.
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.

Course Syllabus

C1 Course Requirement: Newtonian Mechanics

1. Motion in One-Dimension: 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.
   a. Read Chapter 2, pp. 19 – 40.
   b. Labs:
      1) Average Speed of a Domino
      2) Displacement of a Cart
      3) Velocity and Acceleration of a Cart
      4) Analysis of Pendulum Motion
   c. UT homeworks: 01 – Speed; 02 – Acceleration; 03 – Falling Objects.
   d. Giancoli homework: pp. 42 – 46, #3, 5, 7, 9, 11, 14, 16, 17, 19, 21, 24, 25, 26, 27, 29, 34, 36, 38, 41, 44, 46, 49, 50.
   e. Exam: speed, velocity, and acceleration.
2. Vector Algebra; Vector Components: 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, pp. 48 – 57.
   b. Labs:
      i. Vector Walk
      ii. Physics Education Technology (PhET) Vector Addition Simulation (phet.colorado.edu).
   c. UT homeworks: 04.
   d. Perpendicular vector problems; nonperpendicular vector problems.
   e. Giancoli homework: pp. 70 - 71, #7, 9, 11, and 18.
   f. Exam: vector.
3. Motion in Two-Dimensions: 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.
   a. Read Chapter 3, pp. 57 – 66.
   b. Labs:
      i. Projectile Motion Lab.
      ii. PhET Projectile Motion simulation (phet.colorado.edu).
   c. UT homework 05.

   d. Giancoli homework: pp. 72 – 76, #20, 21, 26, 31, 32, 35, 69, and 70.
   e. Exam: projectile motion.
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; and the conditions and forces involved in static equilibrium conditions.
   a. Read Chapter 4, pp. 77 – 102; Chapter 9, pp. 241 – 244; Lethal Force magazine article; Roll Over magazine article; Emergency Stop magazine article.
   b. Labs:
      i. Inertia.
      ii. F = m·a.
      iii. Elevator lab.
      iv. Tension lab.
      v. Friction lab.
      vi. Forces on a Boom lab.
      vii. Atwood Machine lab.
   c. UT homework: 06 – Newton's laws; 07 – tension; 08 – equilibrium; 09 – friction.
   d. Giancoli homework: Ch. 4, pp. 104 – 107; #2, 4, 5, 6, 7, 10, 14, 19, 21, 23, 28, 30, 35.
   e. Giancoli homework: Ch. 4, pp. 107 – 110; #39, 40, 44, 47, 48, 50, 57, 58, 62.
   f. Exam: Newton's Laws, Tension, and Equilibrium.
   g. Exam: friction.
5. Circular Motion and Gravitation: students learn about the characteristics of uniform circular motion, centripetal acceleration, centripetal force as a net force on horizontal and inclined surfaces and in vertical circles; students learn about Newton's Law of Universal Gravitation and Kepler's Laws and applications of these laws.
   a. Read Ch 5, pp. 112 – 122; pp. 124 – 137; Scared to Death magazine article; Space Myths magazine article.
   b. Labs:
      i. Centripetal Force.
      ii. Acceleration of Gravity.
   c. UT homework: 10 – centripetal force; 11 – gravitation.
   d. Giancoli homework: Ch. 5, pp. 139 – 141, #2, 3, 5, 7, 8, 9, 11, 12, 14, 17, 20.
   e. Giancoli homework: Ch. 5, pp 141 – 143, #25, 27, 29, 31, 32, 36, 37, 39, 45, 46, 49, 53, 56, 57.
   f. Exam: centripetal force.
   g. Exam: gravitation.

6. Work, Energy, and Power: 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.
    a. Read Ch. 6, pp. 145 – 171.
    b. Labs:
        i. Inclined plane.
        ii. Pulley.
        iii. Elastic potential energy.
        iv. Potential to kinetic energy.
    c. UT homework: 12 – work and power; 13 – energy.
    d. Giancoli homework: Ch. 6, pp. 174 – 175 and pp. 177 – 178, #2, 3, 5, 7, 8, 9, 10, 58, 59, 62, 65, 67.
    e. Giancoli homework: Ch. 6, pp. 175 – 177, #19, 22, 23, 25, 28, 29, 33, 35, 39, 41, 42, 47, 50, 52, 53, 55.
    f. Exam: work and power.
    g. Exam: energy.
7. Linear 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. 7, pp. 180 – 194; Multi-ball Collision magazine article.
    b. Labs:
        i. Conservation of Momentum.
        ii. Ballistic Pendulum.
        iii. Impulse and Momentum.
    c. UT homework: 14.
    d. Giancoli homework: Ch. 7, pp. 202 – 205, #3, 5, 7, 11, 15, 17, 20, 21, 23, 25, 26, 30, 33, 38, 42.
    e. Exam: momentum.
8. Torque and Rotational Statics: students learn about the torque about the axis and forces and rotational and translational equilibrium.
    a. Read Ch. 8, pp. 217 – 220, Ch. 9, pp. 244 – 253.
    b. Labs:
        i. Torque Feeler.
        ii. Center of Gravity and Equilibrium.
    c. UT homework: 15.
    d. Giancoli homework: Ch. 8, pp. 235 – 236, #30, 31, 33.

e. Giancoli homework: Ch. 9, pp. 267 – 270, #6, 8, 17, 23, 27, 31, 36, 37, 38.
f. Exam: torque and rotational statics.

C2 Course Requirement: Fluid Mechanics and Thermal Physics

9. Fluids: students learn about density and fluid pressure; hydrostatic pressure; Pascal's Principle; buoyancy and Archimedes' Principle; the equation of continuity; and Bernoulli's equation and its problem-solving applications.
    a. Read Ch. 10, pp. 257 – 294; Life in a Whirl magazine article; Tornadoes magazine article; Why Fluids Flow Faster When Tube is Pinched magazine article; Does Convection or Bernoulli's Principle Make Shower Curtains Flutter Inward magazine article.
    b. Labs:
        i. Archimedes Principle.
        ii. Hydrostatic Pressure.
        iii. Bernoulli's Principle.
    c. UT homework: 16 – static fluids; 17 – fluid dynamics.
    d. Giancoli homework: Ch. 10, pp. 304 – 305, # 7, 11, 12, 16, 17, 19, 23, 24, 26, 27.
    e. Giancoli homework: Ch. 10, pp. 305 – 306, # 35, 36, 37, 39, 40, 43.
    f. Exam: fluids.
10. Temperature and Heat: students learn about temperature and temperature scales; thermal expansion; thermal equilibrium and the Zeroth law of thermodynamics; and the gas laws (Boyle's, Charles', Gay-Lussac's, Ideal).
    a. Read Ch. 13, pp. 384 – 391; Ch. 14, pp. 417 – 437.
    b. Labs:
        i. Linear Expansion.
        ii. Specific Heat.
        iii. Thermal Exchange.
        iv. Heat of Fusion and Vaporization.
    c. UT homework: 18 – linear expansion; 19 – heat exchange; 20 – conductivity.
    d. Giancoli homework: Ch. 13, p. 413, #9, 12, 15, 16, 17, 18.
    e. Giancoli homework: Ch. 14, pp. 439 – 441, #9, 14, 17, 21, 25, 29, 31, 39, 41.
    f. Exam: temperature and heat.
11. Kinetic Theory and Thermodynamics: students learn about the kinetic theory; the mechanical equivalent of heat; heat exchange; the mechanisms of heat transfer; internal energy; and the first and second laws of thermodynamics (including heat engines).
    a. Read Ch. 13, pp. 392 – 402; Ch. 15, pp. 443 – 448; pp. 450 – 461; Engines chapter (How Things Work by L. Bloomfield).
    b. PhET Gas Molecules Simulation (phet.colorado.edu).
    c. UT homework: 21 – kinetic theory; 22 – thermodynamics.

d. Giancoli homework: Ch. 13, pp. 414 – 415, #31, 33, 35, 41, 43, 45, 47, 50, 51, 52.
e. Giancoli homework: Ch. 15, pp. 471 – 473, #1, 2, 3, 5, 7, 9, 17, 19, 20, 21, 23, 24, 25.
f. Exam: kinetic theory and thermodynamics.

C3 Course Requirement: Electricity and Magnetism

12. Electrostatics: students learn about electric charge and static electricity; the laws of electrostatics; the law of conservation of charge; conductors and insulators; methods of charging (including induction); Coulomb's law and its problem-solving applications; electric field lines and electric fields due to various charge distributions and its problem-solving applications.
    a. Read Ch. 16, pp. 476 – 493; Ch. 17, pp. 502 – 510; Thunderstorms magazine article.
    b. Labs:
        i. Electrostatics.
        ii. Coulomb's Law.
        iii. PhET Electric Field Hockey, John Travoltage simulation (phet.colorado.edu).
    c. UT homework: 23 – Coulomb's law; 24 – electric fields.
    d. Giancoli homework: Ch. 16, pp.497 – 499, #3, 5, 7, 11, 13, 17, 19, 21, 23, 27, 29, 31.
    e. Giancoli homework: Ch. 16, pp. 522 – 523, #1, 3, 4, 7, 8, 9, 11, 13, 15, 19, 23.
    f. Exam: Coulomb's law and electric fields.
13. Capacitors and Dielectrics: students learn about electric potential energy; electric potential and the relationship between the potential and the electric field; equipotential lines; the electric potential due to various charge distributions; capacitors and capacitance; capacitors in series and parallel; dielectrics; and the energy stored in a capacitor.
    a. Read Ch. 17, pp. 513 – 517; Ch. 19, pp. 568 – 570.
    b. Lab: Charging and Discharging a Capacitor.
    c. UT homework: 25.
    d. Giancoli homework: Ch. 17, pp. 524 – 525, #31, 33, 34, 35, 37, 39, 41, 43, 45, 47.
    e. Giancoli homework: Ch. 19, p. 583, #37, 39, 42, 43, 44.
    f. Exam: capacitors and dielectrics.
14. Electric Circuits: the students learn about current, resistance, EMF and voltage, and direct current circuits; Ohm's law; factors affecting resistance; resistors in series and parallel; Kirchhoff's Rules; and RC circuits.

   a. Read Ch. 18, pp. 527 – 536; pp. 538 – 541; Ch. 19, pp. 555 567.
   b. Labs:
      i. Conservation of Electric Charge.
      ii. Ohm's Law.
      iii. Resistances in Series and Parallel.
   c. UT homework: 26.
   d. Giancoli homework: Ch. 18, pp. 551 – 553, #5, 7, 9, 11, 13, 15, 17, 23, 27, 29, 31, 35, 37.
   e. Giancoli homework: Ch. 19, pp581 – 582, #2, 7, 8, 11, 13, 14, 15, 19, 20, 21, 25, 26, 27, 28.
   f. Exam: electric circuits.

15. Magnetostatics: students learn about magnetic forces and field lines; how electric currents produce magnetism; the right hand rule; force in a current-carrying wire; the force on a charge moving in a magnetic field; and the magnetic field around a straight current-carrying conductor and between two parallel wires.
    a. Read Ch. 20, pp. 588 – 599.
    b. Labs:
       i. Magnetic Field Patterns.
       ii. Current and Field Strength.
       iii. Magnetic Field Around a Current Bearing Wire.
    c. UT homework: 27.
    d. Giancoli homework: Ch. 20, pp. 622 – 628, pp. 633 – 636, # 1, 3, 5, 7, 8, 13, 17, 21, 22, 27, 29.
    e. Exam: magnetostatics.
16. Electromagnetic Induction: students learn about magnetic flux and induced EMF; Faraday's law of induction; Lenz's law; the EMF induced in a moving conductor; the calculation of the electric field in terms of the magnetic flux density; and transformers.
    a. Read Ch. 21, pp. 622 – 628, pp. 633 – 636.
    b. Labs:
       i. Magnetic Induction.
       ii. Induced Current and Lenz's Law.
    c. UT homework: 28.
    d. Giancoli, Ch. 21, pp. 654 – 656, #1, 3, 5 6, 8, 11, 12, 15, 30, 31, 33, 35, 37.
    e. Exam: electromagnetic induction.

C4 Course Requirement: Waves and Optics

17. Oscillations and Wave Motion: students learn about vibrations; periodic motion; simple harmonic motion; simple pendulums; resonance; wave motion; longitudinal and transverse waves; waves and energy transmission; reflection, refraction, interference, and superposition; standing waves; sound and its characteristics; and the Doppler Effect.
    a. Read Ch. 11, pp. 309 – 320, pp.321 – 337; Ch. 12, pp. 340 – 350, pp. 355 – 369.
    b. Labs:
        i. Pendulum.
        ii. Wave Properties.
        iii. Standing Waves in a String.
        iv. PhET Masses and Springs Simulation (phet.colorado.edu).
    c. UT Homework: 29.
    d. Giancoli homework: Ch. 11, pp. 342 – 345, #1, 3, 5, 9, 11, 13, 15, 17, 22, 28, 31, 34, 35, 39, 45, 51, 53, 55, 57.
    e. Giancoli homework: Ch. 12, pp. 376 - 378, #6, 7, 27, 29, 31, 35, 36, 39, 43, 47, 51, 53, 55.
    f. Exam: oscillations and wave motion.
18. Physical and Geometric Optics: students learn about the ray model of light; the law of reflection; real and virtual images; the formation of images by a plane mirror and by spherical mirrors and their problem-solving applications; the index of refraction; Snell's law; total internal reflection; ray tracing; the lens equation; the production of electromagnetic waves; the electromagnetic spectrum; interference and Young's double slit experiment; diffraction of light; and interference by thin films.
    a. Read Ch. 22, pp. 664 – 666, pp. 669 - 673; Ch. 23, pp. 683 – 714; Ch. 24, pp. 723 – 750.
    b. Labs:
        i. Images Produced by Plane and Curved Mirrors.
        ii. Converging and Diverging Lenses.
        iii. PhET Geometric Optics simulation (phet.colorado.edu).
        iv. Wavelength by Diffraction.
        v. Index of Refraction of Glass.
    c. UT homework: 30 – Mirrors; 31 – Lenses; 32 – Diffraction and Interference.
    d. Giancoli homework: Ch. 22, p. 681, #11, 13, 14, 15, 17.
    e. Giancoli homework: Ch. 23, pp. 718 – 721, #9, 12, 13, 15, 17, 18, 25, 27, 31, 33, 35, 37, 40, 41, 48, 50, 52, 54, 56, 57, 59.
    f. Giancoli homework: Ch. 24, pp. 752 – 754, #, 2, 3, 5, 7, 19, 21, 23, 27, 29, 31, 33, 35, 39, 41.
    g. Exam: geometric optics.

C5 Course Requirements: Atomic and Nuclear Physics

19. Atomic Physics and Quantum Mechanics: students learn about the properties of the electrons; Planck's quantum hypothesis; the photoelectric effect and work function; the Compton effect; the wave nature of matter (deBroglie's wavelength); and atomic spectra.
    a. Read Ch. 27, pp. 823 – 838, pp. 840 – 852.
    b. Labs:
        i. PhET Photoelectric Effect Simulation (phet.colorado.edu).
        ii. Determining Planck's Constant by Line Spectrum of Hydrogen.
    c. UT homework: 33.
    d. Giancoli homework: Ch. 27, pp. 854 – 856, #1, 3, 13, 15, 17, 18, 19, 20, 21, 22, 23, 27, 28, 37, 38, 39.
    e. Exam: atomic physics and quantum effects.
20. Nuclear Physics: students learn about the structure and properties of the nucleus; binding energy and nuclear forces; radioactivity; nuclear reactions and transmutation of elements; nuclear fission and chain reactions; and nuclear fusion.
    a. Read Ch. 30, pp. 916 – 935; Ch. 31, pp. 943 – 958; Ch. 26, pp. 813 – 816.
    b. Labs:
        i. Chain Reaction
        ii. Half-life.
        iii. PhET Nuclear Physics simulation (phet.colorado.edu)
    c. UT homework: 34.
    d. Giancoli homework: Ch. 30, pp. 940 – 941, #1, 2, 10, 11, 13, 14, 15, 16, 19, 21, 23, 24, 25, 27, 29.
    e. Giancoli homework: Ch. 31, pp. 970 – 971, #1, 5, 7, 9, 11, 17, 19, 21, 25, 27, 31.
    f. Exam: nuclear physics.

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Laboratory Investigations and Goals

Syllabus

21. Labs for Motion in One-Dimension:
        i. Average Speed of a Domino: student conducted.
            1. Students vary the interval spacing between a number of dominos to determine/graph the average speed at which the dominos fall and to examine the relationship between average spacing and speed.
            2. Completion time: 45 minutes.
        ii. Displacement of a Cart: student conducted.

1. Students collect/graph displacement and time data for the purpose of determining average speed.
2. Completion time: 45 minutes.

iii. Velocity and Acceleration of a Cart: 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.

iv. Analysis of Pendulum Motion: student conducted.

1. Students measure the motion of a swinging pendulum and analyze the distance traveled over time to determine/graph the speed and acceleration of the pendulum.
2. Completion time: 45 minutes.

22. Labs for Vector Algebra; Vector Components:

i. Vector Walk: student conducted.

1. Students arrange various length sticks in random head to tail order to determine the resultant vector, which is the same regardless of the order in which the sticks are used.
2. Completion time: 20 minutes.

ii. 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.

23. Labs for Motion in Two-Dimensions:

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: 90 minutes.

ii. PhET Projectile Motion simulation (http://phet.colorado.edu): virtual.

1. Students can vary the type of projectile, launch angle, mass and 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.

24. Labs for Newton's Laws of Motion:
    i. Inertia: student conducted.
        1. Students use an inertia dumbbell and tape to evaluate the effect of a sharp jerk and a slow pull on the acceleration of the mass.
        2. Completion time: 20 minutes.
    ii. F = m·a: 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.
    iii. Elevator lab: student conducted.
        1. Students ride up and down in an elevator on a bathroom scale to evaluate the acceleration of the elevator on their mass in the vertical direction.
        2. Completion time: 20 minutes.
    iv. Tension lab: student conducted.
        1. Students vary the mass attached to a system of scales and tethers to evaluate the tension at various points in the system.
        2. Completion time: 45 minutes.

v. Friction lab: 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.

vi. Forces on a Boom lab: student conducted.
   1. Students measure the forces in a triangular system to evaluate equilibrium situations and resolve forces at angles into horizontal and vertical components.
   2. Completion time: 45 minutes.

vii. Atwood Machine lab: 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: 1 hour.

25. Labs for Circular Motion and Gravitation:

i. 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: 1 hour.

ii. Acceleration of Gravity: student conducted.
   1. Students analyze the distance a mass falls over time to determine the acceleration of gravity.
   2. Completion time: 30 minutes.

26. Labs for Work, Energy, and Power:

i. Inclined plane: student conducted.
   1. Students determine the work output, work input, mechanical advantage, and efficiency as a mass is raised to a specified height using an inclined plane for several different angles.
   2. Completion time: 45 minutes.

ii. Pulley: student conducted.
   1. Students measure the force required to raise a mass and determine the mechanical advantage and efficiency of pulley systems.
   2. Completion time: 45 minutes.

iii. Elastic potential energy: student conducted.
   1. Students determine the elastic constant and stored potential energy for springs and rubber bands, alone and in combinations.

2. Completion time: 45 minutes.

iv. Potential to kinetic energy: student conducted.

1. Students determine the potential energy, kinetic energy, and frictional losses for an object moving down an inclined plane at various angles to examine the law of conservation of energy.
2. Completion time: 45 minutes.

27. Labs for Linear Momentum:
    i. Conservation of Momentum: student conducted.
        1. Students measure the velocity of carts of varying mass traveling in opposite directions to evaluate the law of conservation of momentum.
        2. Completion time: 45 minutes.
    ii. 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.
28. Labs for Torque and Rotational Statics:
    i. Torque Feeler: student conducted.
        1. Students move a mass along a meterstick held in their hand from their fingers to the end of the meterstick to experience how increasing the torque (or lever) arm influences the net torque.
        2. Completion time: 5 minutes.
    ii. 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: 30 minutes.
29. Labs for Fluids:
    i. Archimedes Principle: student conducted.
        1. Students measure the weight of an object in a fluid and in air and determine the buoyant force on an object.
        2. Completion time: 20 minutes.
    ii. Hydrostatic Pressure: student conducted.
        1. Students observe the distance water flows out of holes in a container to examine the concept of fluid depth and hydrostatic pressure.
        2. Completion time: 20 minutes.
    iii. Bernoulli's Principle: student conducted.
        1. Students construct a paper wing and place it in front of a box fan to see if it will produce lift.
        2. Completion time: 20 minutes.
30. Labs for Temperature and Heat:
    i. Linear Expansion: student conducted.

1. Students measure the expansion of different metal rods and determine the coefficient of linear expansion for the metal.
2. Completion time: 90 minutes.

ii. Specific Heat: student conducted.

1. Students place a heated metal in water and use the law of heat exchange to determine the specific heat of the metal.
2. Completion time: 30 minutes.

iii. Thermal Exchange: student conducted.

1. Students use the method of mixtures to determine the final temperature of a mixture of hot and cold water.
2. Completion time: 30 minutes.

iv. Heat of Fusion and Vaporization: student conducted.

1. Students use the method of mixtures to determine the heat of fusion of ice and the heat of vaporization of water.
2. Completion time: 90 minutes.

31. Labs for Kinetic Theory and Thermodynamics:

i. PhET Gas Molecules Simulation (http://phet.colorado.edu): virtual.

1. Students pump gas molecules into a box and vary the volume, heat content, gravity, and molecular mass to examine how the properties of the gas vary in relation to each other.
2. Completion time: 45 minutes.

32. Labs for Electrostatics:

i. Electrostatics: student conducted.

1. Students use pith balls, an electroscope, and a friction rod kit to observe the behavior of charged objects.
2. Completion time: 30 minutes.

ii. 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.

iii. PhET Electric Field Hockey, John Travoltage 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.

33. Labs for 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.
2. Completion time: 1 hour.

34. Labs for Electric Circuits:
    i. Conservation of Electric Charge: student conducted.
        1. Students use an ammeter to measure the current at various locations in series and parallel circuits to evaluate the law of conservation of charge.
        2. Completion time: 1 hour.
    ii. 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.
    iii. 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 and parallel circuits.
        2. Completion time: 45 minutes.
35. Labs for Magnetostatics:
    i. Magnetic Field Patterns: student conducted.
        1. Students use an assortment of magnets, compasses, iron filings, and paper or cardboard to map the magnetic fields produced by the arrangement of the magnets.
        2. Completion time: 45 minutes.
    ii. Current and Field Strength: 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.
    iii. Magnetic Field around a Current Bearing Wire: student conducted.
        1. Students use compasses, a bar magnet, iron filings, and an electric circuit to study the relationship between the direction of electron flow in a wire and the direction of the resultant magnetic field around the wire.
        2. Completion time: 45 minutes.
36. Labs for Electromagnetic Induction:
    i. 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.

ii. Induced Current and Lenz's Law: student conducted.

1. Students use various coils of wire, different magnets, an iron rod and a galvanometer to examine the effect of the number of turns, the strength of the magnetic field, and the rate of the magnetic flux through the coil on an induced EMF and induced current.
2. Completion time: 45 minutes.

37. Labs for Oscillations and Wave Motion:

i. 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: 1 hour.

ii. Wave Properties: student conducted.

1. Students use a ripple tank with a vibrating wave source to examine the properties of waves: reflection, refraction, diffraction, and interference.

iii. Standing Waves in a String: student conducted.

1. Students use an electric string vibrator, masses, and a pulley to examine nodes and antinodes, and the relationship between the tension and the wavelength in a vibrating string to the natural frequency of a vibrating string system.
2. Completion time: 45 minutes.

iv. PhET Masses and Springs Simulation (http://phet.colorado.edu): virtual.

1. Students manipulate masses, the stiffness of springs, frictional forces, and gravity to evaluate the effect on the energy of the spring-mass system (elastic potential, gravitational potential, kinetic, and thermal energies).
2. Completion time: 45 minutes.

38. Labs for Physical and Geometric Optics:

i. Images Produced by Plane and Curved Mirrors: student conducted.

1. Students use an optical bench, plane mirrors, and curved mirrors to examine the laws of reflection and the type and position of the image formed.
2. Completion time: 45 minutes.

ii. Converging and Diverging Lenses: student conducted.

1. Students use an optical bench and converging and diverging lenses to determine the focal length of the lenses and the image forming characteristics of the lenses. Students should also gain an understanding of the + and – sign conventions used in lens optics.
2. Completion time: 45 minutes.

iii. PhET Geometric Optics simulation (http://phet.colorado.edu): virtual.
1. Students manipulate the radius of curvature, index of refraction, and the diameter of a convex lens and the object distance to examine the effect of the variables on the formation of the image.
2. Completion time: 30 minutes.

iv. PhET Wave Interference simulation (http://phet.colorado.edu): virtual.
1. Students make waves with a dripping faucet, audio speaker, or laser and add a second wave source, a single slit, or two slits to observe the resulting interference pattern.
2. Completion time: 30 minutes.

v. Wavelength by Diffraction: student conducted.
1. Students use a bright line light source and a diffraction grating to produce interference patterns in order to determine the wavelength of light by analysis of the diffraction pattern.
2. Completion time: 45 minutes.

vi. Index of Refraction of Glass: student conducted.
1. Students use a ray box, a glass plate, and a glass prism to measure the angle of refraction for the refracted ray for the purpose of determining the index of refraction of glass.
2. Completion time: 45 minutes.

39. Labs for Atomic Physics and Quantum Mechanics:
    i. PhET Photoelectric Effect Simulation (http://phet.colorado.edu): virtual.
        1. Students are allowed to vary the type of surface illuminated, the wavelength of incident light, and the intensity of the incident light to evaluate the number and energy of photoelectrons released from the illuminated surface.
        2. Completion time: 30 minutes.
    ii. Determining Planck's Constant by Line Spectrum of Hydrogen: student conducted.
        1. Students use a hydrogen gas discharge tube and a diffraction grating to determine the position of the visible lines in the Balmer series to be used to determine the value for Planck's constant.
        2. Completion time: 45 minutes.
40. Labs for Nuclear Physics:
    i. Chain Reaction: student conducted.
        1. Students compare falling times for various linear arrangements of dominos to falling times for randomly arranged dominos to simulate a chain reaction.
        2. Completion time: 30 minutes.
    ii. Half-life: student conducted.
        1. Students use pennies or M & M's to simulate/graph exponential decay to develop an understanding of half-life and radioactive decay.
        2. Completion time: 30 minutes.
    iii. PhET Nuclear Physics simulation (http://phet.colorado.edu): virtual.
        1. Students can manipulate variables for a chain reaction, observe alpha particles escape from a Polonium nucleus, observe fission of a Uranium nucleus, and control energy production in a nuclear reactor.
        2. Completion time: 30 minutes.