AP Physics C - Mechanics
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 Mechanics course consists of six general topics of study:

1. Kinematics.
2. Newtonian mechanics.
3. Work, Energy, and Power.
4. Systems of Particles and Linear Momentum.
5. Circular Motion and Rotation.
6. Oscillations and Gravitation.

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 are 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 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. 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. Kleppner, Daniel, and Norman Ramsey. Quick Calculus: A Self-Teaching Guide, 2nd ed. New York: John Wiley & Sons, 1985.
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. 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.
10. 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

C1 Course Requirement: Kinematics.

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. The mathematical relationships between position, velocity, and acceleration will be emphasized. Students will get practice solving a system of equations and simple differential equations.
   a. Read Chapter 2 pp. 19 – 41.
   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. Tipler homework: pp. 44 – 49, #4, 5, 6, 7, 14, 17, 19, 21, 22, 24, 27, 29, 34, 35, 36, 37, 38, 42, 51, 53, 55, 57, 58, 59, 60, 66, 69, 72, 73, 74, 79, 80, 82, and 83.
    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. 54 – 64.
    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. Tipler homework: pp. 74 – 78, # 1, 4, 5, 7, 9, 15, 17, 19, 31, 32, 3, 37, 42, 43, and 47.
    f. Exam: Vectors.
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. Students will get practice solving a system of equations.
    a. Read Chapter 3, pp. 64 – 72.
    b. Labs:
        i. Projectile Motion Lab.
        ii. PhET Projectile Motion simulation (phet.colorado.edu).
    c. UT homework 05.
    d. Tipler homework: pp. 78 – 81, #50, 51, 55, 57, 58, 62, 63, 67, 68, 69, 70, 74, 77, 78, 81, 83, 87, 102, and 109.
    e. Exam: Projectile Motion.

C2 Course Requirement: Newtonian Mechanics.

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 free-body diagram will accompany homework problems. Students will get practice solving a system of equations.

   a. Read Chapter 4, pp. 83 - 102; Chapter 5, pp. 114 – 124, Chapter 5, pp. 133 – 136, Lethal Force magazine article; Roll Over magazine article; and the 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.
      viii. Terminal Velocity and Air Resistance lab.
   c. UT homework: 06 – Newton's laws; 07 – tension; 08 – static equilibrium; 09 – friction.
   d. Tipler homework: pp. 105 – 111, #10, 12, 13, 15, 16, 23, 27, 28, 29, 31, 32, 33, 38, 43, 45, 46, 47, 48, 49, 51, 53, 56, 63, 65, 67, 68, 69, 71, 72, 81, and 82.
   e. Tipler homework: pp. 139 – 142; #5, 9, 11, 12, 15, 17 18, 21, 23, 25, 28, 29, 32, and 33.
   f. Tipler homework: p. 145, # 82, 83, 85, and 87.
   g. Exam: Newton's Laws, Tension, and Equilibrium.
   h. Exam: Friction.

C3 Course Requirement: Work, Energy, and Power.

5. 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 the mechanical power with constant acceleration or an average force. The dot product will be discussed as it describes the work performed on an object.
   a. Read Chapter 6, pp. 148 – 168; Chapter 7, pp. 178 – 195.
   b. Labs:
      i. Inclined plane.
      ii. Pulley.
      iii. Elastic potential energy.
      iv. Potential to kinetic energy.
   c. UT homework: 10 – work and power; 11 – energy.
   d. Tipler homework: pp. 171 – 176, #7, 8, 9, 10, 12, 13, 14, 20, 23, 24, 25, 26, 35, 37, 41, 44, 57, 60, 79, and 85.

e. Tipler homework: pp. 203 – 209, #6, 8, 9, 13, 21, 43, 47, 49, 51, 77, 80, and 81.
f. Exam: Work and Power.
g. Exam: Energy.

C4 Course Requirement: Systems of Particle and Linear Momentum.

6. Center of Mass: students learn how to determine the center of mass for a symmetric object or objects; students examine the relationship between the velocity and acceleration of the center of mass and linear momentum, and students also relate the center of gravity to gravitational potential energy.
   a. Read Chapter 8, pp. 213 – 221.
   b. Lab: Center of Mass.
   c. UT homework: 12
   d. Tipler homework: pp. 246 – 247, # 2, 3, 5, 9, 10, 15, and 19.
   e. Exam: Center of Mass.
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. Students will get practice solving a system of equations involving kinetic energy and momentum. Students will also learn about frames of reference and the motion of objects in an accelerating frame of reference.
   a. Read Chapter 8, pp. 221 – 241.
   b. Labs:
      i. Conservation of Momentum.
      ii. Ballistic Pendulum.
      iii. Impulse and Momentum.
   c. UT homework: 13.
   d. Tipler homework: pp. 248 – 252, #31, 32, 35, 36, 37, 40, 41, 45, 46, 48, 49, 52, 59, 60, 61, 62, 66, 69, 70, 72, 73, 77, 86, 88, and 89.
   e. Exam: Momentum.

C5 Course Requirement: Circular Motion and Rotation.

8. Circular Motion: 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 will get practice solving a system of equations.
   a. Read Chapter 5, pp. 125 - 133; Scared to Death magazine article.
   b. Lab: Centripetal Force.
   c. UT homework: 14.
   d. Tipler homework: pp. 142 – 145, #44, 47, 49, 51, 52, 53, 54, 55, 58, 60, 61, 66, 68, 72, 7, 74, and 75.

e. Exam: Centripetal Force.

9. Torque and Rotational Statics: students learn about the torque about the axis and forces and rotational and translational equilibrium; students learn about the factors that influence the rotational inertia of symmetrical objects; students learn the parallel-axis theorem.
    a. Read Chapter 9, pp. 257 - 266.
    b. Labs:
        i. Torque Feeler.
        ii. Center of Gravity and Equilibrium.
        iii. Moment of Inertia.
    c. UT homework: 15.
    d. Tipler homework: pp. 282 – 286, #1, 3, 5, 7, 9, 10, 14, 15, 17, 22, 23, 24, 25, 29, 30, 31, 33, 34, and 37.
    e. Exam: Torque and Rotational Statics.
10. Rotational Kinematics and Dynamics: students learn about the relationship between linear and angular quantities; students learn about rotational inertia and the relationship between torque, rotational inertia, and angular acceleration; students use torque and rotational inertia to solve rotational dynamics problems. Students learn the right-hand rule to determine the direction of an angular velocity. Students learn how torque and rotational inertia affect the motion of stings over pulleys and the motion of rolling objects. Students learn about angular momentum. Students apply the rotational dynamic principles to the conservation laws for momentum and energy.
    a. Read Chapter 9, pp. 267 – 281; Chapter 10, pp. 295 - 309.
    b. Labs:
        i. Rotational Energy and Momentum.
        ii. Rotational Motion and Moment of Inertia.
    c. UT homework: 16 – Rotational Dynamics; 17 – Angular Momentum.
    d. Tipler homework: pp. 287 – 291, #49, 51, 54, 57, 60, 61, 62, 65, 68, 73, 83, 85, 89, and 93.
    e. Tipler homework: pp. 313 – 316, #15, 16, 19, 21, 23, 26, 36, and 38.
    f. Exam: Rotational Dynamics and Angular Momentum.

C6 Course Requirement: Oscillations and Gravitation.

11. Oscillations and Gravitation: students will construct and interpret position – time graphs, velocity – time graphs, and acceleration – time graphs for the simple harmonic motion of a mass on a string, a pendulum, or any object demonstrating periodic motion. The mathematical relationships between position, velocity, and acceleration will be emphasized. Students will also learn about the energy relationships that describe simple

harmonic motion. Students learn about Newton's Law of Universal Gravitation and Kepler's Laws and applications of these laws.

a. Read: Chapter 14, pp. 403 – 430; Chapter 11, pp. 321 – 339; Space Myths magazine article.
b. Labs:
    i. Pendulum.
    ii. Hooke's Law and Simple Harmonic Motion.
    iii. PhET Masses and Springs Simulation.
    iv. Standing Waves in a String
    v. Acceleration of Gravity.
c. UT homework: 18 – oscillations; 19 - gravitation.
d. Tipler homework: pp. 433 – 437, #6, 7, 9, 11, 15, 17, 21, 23, 24, 25, 29, 31, 33, 35, 37, 38, 44, 45, 50, 51, 53, 59, and 81.
e. Tipler homework: pp. 344 – 349, #6, 8, 13, 14, 15, 20, 21, 23, 27, 39, 41, 49, 50, 61, 65, 91, 93, and 99.
f. Exam: Oscillations.
g. Exam: Gravitation and Kepler's Laws.

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Laboratory Investigations and Goals

Syllabus

12. 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.

13. 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.
14. 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.
15. 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. $F = m \cdot a$: 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.

viii. Terminal Velocity and Air Resistance lab: student conducted.
    1. Students use coffee filters and a motion detector to investigate the terminal velocity of a falling object. Students also examine the relationship between velocity and air resistance.
    2. Completion time: 1 hour.

16. 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.

17. Lab for Center of Mass:
  i. Center of Mass (String and Sticky Tape Experiment 1.15): student conducted.
    1. Students use simple materials to find the center of mass for various asymmetric shapes cut out of paper. Students also explore their own center of mass as they bend over while keeping their legs and rear end against a wall.
    2. Completion time: 30 minutes.

18. 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.
- 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.

19. Lab for Circular Motion:
    - 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.
20. 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.
    - iii. Moment of Inertia (String and Sticky Tape Experiment 1.33 and 1.35): student conducted.
      1. Students use simple materials to examine the behavior of a rotational system set spinning by a weight. Students also examine how the distribution of mass influences rotational inertia and angular acceleration.
      2. Completion time: 45 minutes.
21. Labs for Rotational Kinematics and Dynamics:
    - i. Rotational Energy and Momentum (String and Sticky Tape Experiment 1.36): student conducted.

1. Students use simple materials to examine the relationship between the moment arm (rotational inertia) and rotational energy.
2. Completion time: 30 minutes.

ii. Rotational Motion and Moment of Inertia: student conducted.
1. Students use a rotational inertia apparatus to examine the relationship between torque, rotational inertia, and rotational energy. Students also examine the factors on which rotational inertia depends. The parallel-axis theorem is also examined.
2. Completion time: 1 hour.

22. Labs for Oscillations and Gravitation:

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. Hooke's Law and Simple Harmonic Motion: student conducted.
1. Students use a Hooke's law apparatus to examine the relationship between the period of oscillation of the spring and the oscillating mass and the spring constant.
2. Completion time: 45 minutes.

iii. 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.

iv. 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.

v. 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.