ADVANCED PLACEMENT PHYSICS C

AP Physics C: Mechanics is equivalent to a one-semester, calculus-based, college-level physics course, especially appropriate for students planning to specialize or major in physical science or engineering. The course explores topics such as kinematics; Newton's laws of motion; work, energy and power; systems of particles and linear momentum; circular motion and rotation; and oscillations and gravitation. Introductory differential and integral calculus is used throughout the course.

AP Physics C: Electricity and Magnetism is equivalent to a one-semester, calculus-based, college-level physics course, designed to follow AP Physics C: Mechanics. The course explores topics such as electrostatics; conductors, capacitors, and dielectrics; electric circuits; magnetic fields; and electromagnetism. Introductory differential and integral calculus is used throughout the course.

Learning Objectives for Laboratory and Experimental Situations
Students establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena. Focusing on these disciplinary practices and experimental skills enables teachers to use the principles of scientific inquiry to promote a more engaging and rigorous experience for AP Physics C: Mechanics students.

Such practices or skills require students to
• Design experiments
• Observe and measure real phenomena
• Organize, display, and critically analyze data
• Analyze sources of error and determine uncertainties in measurement
• Draw inferences from observations and data
• Communicate results, including suggested ways to improve experiments and proposed questions for further study

Students will be able to:

<u>Kinematics</u>

1. Understand the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line.

2. Understand the special case of motion with constant acceleration.

3. Deal with situations in which acceleration is a specified function of velocity and time so they can write an appropriate differential equation $dv/dt=f(v)g(t)$ and solve it for $v(t)$, incorporating correctly a given initial value of v.

4. Know how to deal with displacement and velocity vectors.

5. Understand the general motion of a particle in two dimensions so that, given functions *x(t)* and and *y(t)* which describe this motion, they can determine the components, magnitude, and direction of the particle's velocity and acceleration as functions of time.

6. Understand the motion of projectiles in a uniform gravitational field.

7. Understand the uniform circular motion of a particle.

<u>Newton's Laws of Motion</u>

8. Students should be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

9. Understand the relation between the force that acts on a body and the resulting change in the body's velocity.

10. Understand how Newton's Second Law, **F**=m**a**, applies to a body subject to forces such as gravity, the pull of strings, or contact forces.

11. Analyze situations in which a body moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force.

12. Understand the significance of the coefficient of friction.

13. Understand the effect of fluid friction on the motion of a body.

14. Understand Newton's Third Law so that, for a given force, they can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

15. Apply Newton's Third Law in analyzing the forces of contact between two bodies that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.

16. Know that the tension is constant in a light string that passes over a massless pulley and should be able to use this fact in analyzing the motion of a system of two bodies joined by a string.

17. Solve problems in which application of Newton's Laws leads to two or three simultaneous linear equations involving unknown forces or accelerations.

<u>Work, Energy, and Power</u>

18. Understand the definition of work.

19. Understand the work-energy theorem.

20. Understand the concept of a conservative force.

21. Understand the concept of potential energy.

22. Understand the concepts of mechanical energy and of total energy.

23. Understand conservation of energy.

24. Recognize and solve problems that call for application both of conservation of energy and Newton's Laws.

25. Understand the definition of power.

<u>Systems of Particles, Linear Momentum</u>

26. Understand the technique for finding center of mass.

27. State, prove, and apply the relation between center-of-mass velocity and linear momentum, and between center-of-mass acceleration and net external force for a system of particles.

28. Define center of gravity and to use this concept to express the gravitational potential energy of a rigid body in terms of the position of its center of mass.

29. Understand impulse and linear momentum.

30. Understand linear momentum conservation.

31. Understand frames of reference.

<u>Rotation</u>

32. Understand the concept of torque.

33. Analyze problems in statics.

34. Understand the analogy between translational and rotational kinematics so they can write and apply relations among the angular acceleration, angular velocity, and angular displacement of a body that rotates about a fixed axis with constant angular acceleration.

35. Use the right-hand rule to associate and angular velocity vector with a rotating body.

36. Develop a qualitative understanding of rotational inertia.

37. Develop skill in computing rotational inertia.

38. State and apply the parallel-axis theorem.

39. Understand the dynamics of fixed-axis rotation.

40. Understand the motion of a rigid body along a surface.

41. Use the vector product and the right-hand rule.

42. Understand angular momentum conservation.

Oscillations

43. Understand the kinematics of simple harmonic motion.

44. Apply their knowledge of simple harmonic motion to the case of a mass on a spring.

45. Apply their knowledge of simple harmonic motion to the case of a pendulum.

Gravitation and Planetary Motion

46. Know Newton's Law of Universal Gravitation.

47. Understand the motion of a body in orbit under the influence of gravitational forces so they can:
    - Recognize that the motion does not depend on the body's mass, describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radium of the orbit, and derive expressions for the velocity and period of revolution in such an orbit
    - Prove that Kepler's Third Law must hold for this special case
    - Derive and apply the relations among kinetic energy, potential energy, and total energy for such an orbit
    - State Kepler's three laws of planetary motion and use them to describe in qualitative terms the motion of a body in an elliptic orbit
    - Apply conservation of angular momentum to determine the velocity and radial distance at any point in the orbit
    - Apply angular momentum conservation and energy conservation to relate the speeds of a body at the two extremes of an elliptic orbit

- Apply energy conservation in analyzing the motion of a body that is projected straight up from a planet's surface or that is projected directly toward the planet from far above the surface

Electrostatics

48. Understand the concept of electric field.

49. Understand the concept of electric potential.

50. Understand Coulomb's Law and the principle of superposition.

51. Know the potential function for a point charge.

52. Use the principle of superposition to calculate by integration.

53. Know the fields of highly symmetric charge distributions.

Conductors, Capacitors, and Dielectrics

54. Understand the relationship between field and flux.

55. Understand Gauss's Law.

56. Understand the nature of electric fields in and around conductors.

57. Describe and sketch a graph of the electric field and potential inside and outside a charged conducting sphere.

58. Understand induced charge and electrostatic shielding.

59. Know the definition of capacitance so they can relate stored charge and voltage for a capacitor.

60. Understand energy storage in capacitors.

61. Understand the physics of the parallel-plate capacitor.

62. Understand cylindrical and spherical capacitors.

Electric Circuits

63. Understand the definition of electric current so they can relate the magnitude and direction of the current in a wire or ionized medium to the rate of flow of positive and negative charge.

64. Understand conductivity, resistivity, and resistance.

65. Understand the behavior of series and parallel combinations of resistors.

66. Understand the properties of ideal and real batteries.

67. Apply Ohm's Law and Kirchoff's rules.

68. Understand the properties of voltmeters and ammeters.

69. Understand the behavior of capacitors connected in series or in parallel.

70. Understand energy storage in capacitors.

71. Calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors.

72. Understand the discharging or charging of a capacitor through a resistor.

73. Develop skill in analyzing the behavior of circuits containing several capacitors and resistors.

<u>Magnetostatics</u>

74. Understand the force experienced by a charge particle in a magnetic field.

75. Understand the force experienced by a current in a magnetic field.

76. Understand the magnetic field produced by a long straight current-carrying wire.

77. Understand the Biot-Savart Law.

78. Understand the statement and application of Ampere's Law in integral form.

79. Develop skill in applying the superposition principle so they can determine the magnetic field produced by combinations of the configurations listed above.

<u>Electromagnetism</u>

80. Understand the concept of magnetic flux.

81. Understand Faraday's Law and Lenz's Law.

82. Develop skill in analyzing the forces that act on induced currents so they can solve simple problems involving the mechanical consequences of electromagnetic induction.

83. Understand the concept of inductance.

84. Develop skill in analyzing circuits containing inductors and resistors.

LABORATORY AND EXPERIMENTAL SITUATIONS

These objectives overlay the content objectives, and are assessed in the context of those objectives.

1. <u>Design experiments</u>
   Students should understand the process of designing experiments, so they can:
   a. Describe the purpose of an experiment or a problem to be investigated.
   b. Identify equipment needed and describe how it is to be used.
   c. Draw a diagram or provide a description of an experimental setup.
   d. Describe procedures to be used, including controls and measurements to be taken.

2. <u>Observe and measure real phenomena</u>
   Students should be able to make relevant observations, and be able to take measurements with a variety of instruments (cannot be assessed via paper-and-pencil examinations).

3. <u>Analyze data</u>
   Students should understand how to analyze data, so they can:
   a. Display data in graphical or tabular form.
   b. Fit lines and curves to data points in graphs.
   c. Perform calculations with data.
   d. Make extrapolations and interpolations from data.

4. <u>Analyze errors</u>
   Students should understand measurement and experimental error, so they can:
   a. Identify sources of error and how they propagate.
   b. Estimate magnitude and direction of errors.
   c. Determine significant digits.
   d. Identify ways to reduce error.

5. <u>Communicate results</u>

Students should understand how to summarize and communicate results, so they can:

a. Draw inferences and conclusions from experimental data.
b. Suggest ways to improve experiment.
c. Propose questions for further study.

Science Practice for AP Physics II

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

1.1. The student can create representations and models of natural or man-made phenomena and systems in the domain.
1.2. The student can describe representations and models of natural or man-made phenomena and systems in the domain.
1.3. The student can refine representations and models of natural or man-made phenomena and systems in the domain.
1.4. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
1.5. The student can re-express key elements of natural phenomena across multiple representations in the domain.

Science Practice 2: The student can use mathematics appropriately.

2.1 The student can justify the selection of a mathematical routine to solve problems.
2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
2.3 The student can estimate numerically quantities that describe natural phenomena.

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

3.1 The student can pose scientific questions.
3.2 The student can refine scientific questions.
3.3 The student can evaluate scientific questions.

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

[Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction, and/or archived data.]

4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question.
4.2 The student can design a plan for collecting data to answer a particular scientific question.

4.3 The student can collect data to answer a particular scientific question.
4.4 The student can evaluate sources of data to answer a particular scientific question.

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

5.1 The student can analyze data to identify patterns or relationships.
5.2 The student can refine observations and measurements based on data analysis.
5.3 The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

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

6.1 The student can justify claims with evidence.
6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.
6.3 The student can articulate the reasons that scientific explanations and theories are refined or replaced.
6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.
6.5 The student can evaluate alternative scientific explanations.

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

7.1 The student can connect phenomena and models across spatial and temporal scales.
7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.