Content Outline for AP Physics C

A more detailed topic outline is contained in the "Learning Objectives for AP Physics C," which follow this outline.

Content Area	*Percentage Goals for Exams*
AP Physics C: Mechanics	100%
A. Kinematics (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity, and acceleration) 1. Motion in one dimension 2. Motion in two dimensions, including projectile motion	18%
B. Newton's laws of motion 1. Static equilibrium (first law) 2. Dynamics of a single particle (second law) 3. Systems of two or more objects (third law)	20%
C. Work, energy, power 1. Work and work–energy theorem 2. Forces and potential energy 3. Conservation of energy 4. Power	14%
D. Systems of particles, linear momentum 1. Center of mass 2. Impulse and momentum 3. Conservation of linear momentum, collisions	12%
E. Circular motion and rotation 1. Uniform circular motion 2. Torque and rotational statics 3. Rotational kinematics and dynamics 4. Angular momentum and its conservation	18%
F. Oscillations and gravitation 1. Simple harmonic motion (dynamics and energy relationships) 2. Mass on a spring 3. Pendulum and other oscillations 4. Newton's law of gravity 5. Orbits of planets and satellites a. Circular b. General	18%

Content Area	*Percentage Goals for Exams*
AP Physics C: Electricity and Magnetism	100%
A. Electrostatics	30%
1. Charge and Coulomb's law	
2. Electric field and electric potential (including point charges)	
3. Gauss's law	
4. Fields and potentials of other charge distributions	
B. Conductors, capacitors, dielectrics	14%
1. Electrostatics with conductors	
2. Capacitors	
a. Capacitance	
b. Parallel plate	
c. Spherical and cylindrical	
3. Dielectrics	
C. Electric circuits	20%
1. Current, resistance, power	
2. Steady-state direct current circuits with batteries and resistors only	
3. Capacitors in circuits	
a. Steady state	
b. Transients in RC circuits	
D. Magnetic Fields	20%
1. Forces on moving charges in magnetic fields	
2. Forces on current-carrying wires in magnetic fields	
3. Fields of long current-carrying wires	
4. Biot–Savart law and Ampere's law	
E. Electromagnetism	16%
1. Electromagnetic induction (including Faraday's law and Lenz's law)	
2. Inductance (including LR and LC circuits)	
3. Maxwell's equations	

Laboratory and experimental situations: Each exam will include one or more questions or parts of questions posed in a laboratory or experimental setting. These questions are classified according to the content area that provides the setting for the situation, and each content area may include such questions. These questions generally assess some understanding of content as well as experimental skills, as described on the following pages.

Miscellaneous: Each exam may include occasional questions that overlap several major topical areas or questions on miscellaneous topics such as identification of vectors and scalars, vector mathematics, or graphs of functions.

Learning Objectives for AP Physics C

These course objectives are intended to elaborate on the content outline for Physics C. In addition to the content areas, objectives are included for laboratory skills, which have become an important part of the AP Physics C Exams.

The objectives listed below are generally representative of the cumulative content of recently administered exams, although no single exam can cover them all. It is reasonable to expect that future exams will continue to sample primarily from among these objectives. However, there may be an occasional question that is within the scope of the included topics but is not specifically covered by one of the listed objectives. Questions may also be based on variations or combinations of these objectives, rephrasing them but still assessing the essential concepts.

The objectives listed below are continually revised to keep them as current as possible with the content outline and the coverage of the exams.

Objectives for AP® Physics C

AP PHYSICS C: MECHANICS

A. Kinematics (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity and acceleration)

1. Motion in one dimension

a) Students should understand the general relationships among position, velocity and acceleration for the motion of a particle along a straight line, so that:

1) Given a graph of one of the kinematic quantities, position, velocity or acceleration, as a function of time, they can recognize in what time intervals the other two are positive, negative, or zero and can identify or sketch a graph of each as a function of time.

2) Given an expression for one of the kinematic quantities, position, velocity or acceleration, as a function of time, they can determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.

b) Students should understand the special case of motion with constant acceleration, so they can:

1) Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.

2) Use the equations $v_x = v_{x0} + a_x t$, $x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$, and $v_x^2 = {v_{x0}}^2 + 2a_x\left(x - x_0\right)$ to solve problems involving one-dimensional motion with constant acceleration.

c) Students should know how to deal with situations in which acceleration is a specified function of velocity and time so they can write an appropriate differential equation and solve it for $v(t)$ by separation of variables, incorporating correctly a given initial value of v.

2. **Motion in two dimensions, including projectile motion**

   a) Students should be able to add, subtract and resolve displacement and velocity vectors, so they can:

      1) Determine components of a vector along two specified, mutually perpendicular axes.

      2) Determine the net displacement of a particle or the location of a particle relative to another.

      3) Determine the change in velocity of a particle or the velocity of one particle relative to another.

   b) Students should understand the general motion of a particle in two dimensions so that, given functions $x(t)$ 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.

   c) Students should understand the motion of projectiles in a uniform gravitational field, so they can:

      1) Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components.

      2) Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity.

B. Newton's laws of motion

1. **Static equilibrium (first law)**

   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.

2. **Dynamics of a single particle (second law)**

   a) Students should understand the relation between the force that acts on an object and the resulting change in the object's velocity, so they can:

      1) Calculate, for an object moving in one dimension, the velocity change that results when a constant force $\vec{F}$ acts over a specified time interval.

      2) Calculate, for an object moving in one dimension, the velocity change that results when a force $\vec{F}(t)$ acts over a specified time interval.

      3) Determine, for an object moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the object.

   b) Students should understand how Newton's second law, $\sum \vec{F} = \vec{F}_{net} = m\vec{a}$, applies to an object subject to forces such as gravity, the pull of strings, or contact forces, so they can:

      1) Draw a well-labeled, free-body diagram showing all real forces that act on the object.

      2) Write down the vector equation that results from applying Newton's second law to the object, and take components of this equation along appropriate axes.

c) Students should be able to analyze situations in which an object 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, such as motion up or down with constant acceleration.

d) Students should understand the significance of the coefficient of friction, so they can:

1) Write down the relationship between the normal and frictional forces on a surface.

2) Analyze situations in which an object moves along a rough inclined plane or horizontal surface.

3) Analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction.

e) Students should understand the effect of drag forces on the motion of an object, so they can:

1) Find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity.

2) Describe qualitatively, with the aid of graphs, the acceleration, velocity and displacement of such a particle when it is released from rest or is projected vertically with specified initial velocity.

3) Use Newton's second law to write a differential equation for the velocity of the object as a function of time.

4) Use the method of separation of variables to derive the equation for the velocity as a function of time from the differential equation that follows from Newton's second law.

5) Derive an expression for the acceleration as a function of time for an object falling under the influence of drag forces.

3. Systems of two or more objects (third law)

a) Students should understand Newton's third law so that, for a given system, they can identify the force pairs and the objects on which they act, and state the magnitude and direction of each force.

b) Students should be able to apply Newton's third law in analyzing the force of contact between two objects that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.

c) Students should 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 objects joined by a string.

d) Students should be able to solve problems in which application of Newton's laws leads to two or three simultaneous linear equations involving unknown forces or accelerations.

C. Work, energy, power

1. Work and the work-energy theorem

a) Students should understand the definition of work, including when it is positive, negative or zero, so they can:

1) Calculate the work done by a specified constant force on an object that undergoes a specified displacement.
2) Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.
3) Use integration to calculate the work performed by a force $\vec{F}(x)$ on an object that undergoes a specified displacement in one dimension.
4) Use the scalar product operation to calculate the work performed by a specified constant force $\vec{F}$ on an object that undergoes a displacement in a plane.

b) Students should understand and be able to apply the work-energy theorem, so they can:

1) Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.
2) Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.
3) Apply the theorem to determine the change in an object's kinetic energy and speed that result from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.

2. Forces and potential energy

a) Students should understand the concept of a conservative force, so they can:

1) State alternative definitions of "conservative force" and explain why these definitions are equivalent.
2) Describe examples of conservative forces and non-conservative forces.

b) Students should understand the concept of potential energy, so they can:

1) State the general relation between force and potential energy, and explain why potential energy can be associated only with conservative forces.
2) Calculate a potential energy function associated with a specified one-dimensional force $\vec{F}(x)$.
3) Calculate the magnitude and direction of a one-dimensional force when given the potential energy function $U(x)$ for the force.
4) Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.
5) Calculate the potential energy of one or more objects in a uniform gravitational field.

3. **Conservation of energy**
   a) Students should understand the concepts of mechanical energy and of total energy, so they can:
      1) State and apply the relation between the work performed on an object by non-conservative forces and the change in an object's mechanical energy.
      2) Describe and identify situations in which mechanical energy is converted to other forms of energy.
      3) Analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force.
   b) Students should understand conservation of energy, so they can:
      1) Identify situations in which mechanical energy is or is not conserved.
      2) Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine.
      3) Apply conservation of energy in analyzing the motion of objects that move under the influence of springs.
      4) Apply conservation of energy in analyzing the motion of objects that move under the influence of other non-constant one-dimensional forces.
   c) Students should be able to recognize and solve problems that call for application both of conservation of energy and Newton's laws.
4. **Power**

   Students should understand the definition of power, so they can:
   a) Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed).
   b) Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work.

D. Systems of particles, linear momentum

1. **Center of mass**
   a) Students should understand the technique for finding center of mass, so they can:
      1) Identify by inspection the center of mass of a symmetrical object.
      2) Locate the center of mass of a system consisting of two such objects.
      3) Use integration to find the center of mass of a thin rod of non-uniform density.
   b) Students should be able to understand 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.

c) Students should be able to define center of gravity and to use this concept to express the gravitational potential energy of a rigid object in terms of the position of its center of mass.

2. Impulse and momentum

Students should understand impulse and linear momentum, so they can:

a) Relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects.

b) Relate impulse to the change in linear momentum and the average force acting on an object.

c) State and apply the relations between linear momentum and center-of-mass motion for a system of particles.

d) Calculate the area under a force versus time graph and relate it to the change in momentum of an object.

e) Calculate the change in momentum of an object given a function $\vec{F}(t)$ for the net force acting on the object.

3. Conservation of linear momentum, collisions

a) Students should understand linear momentum conservation, so they can:

1) Explain how linear momentum conservation follows as a consequence of Newton's third law for an isolated system.

2) Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.

3) Apply linear momentum conservation to one-dimensional elastic and inelastic collisions and two-dimensional completely inelastic collisions.

4) Apply linear momentum conservation to two-dimensional elastic and inelastic collisions.

5) Analyze situations in which two or more objects are pushed apart by a spring or other agency, and calculate how much energy is released in such a process.

b) Students should understand frames of reference, so they can:

1) Analyze the uniform motion of an object relative to a moving medium such as a flowing stream.

2) Analyze the motion of particles relative to a frame of reference that is accelerating horizontally or vertically at a uniform rate.

E. Circular motion and rotation

1. Uniform circular motion

Students should understand the uniform circular motion of a particle, so they can:

a) Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

b) Describe the direction of the particle's velocity and acceleration at any instant during the motion.

c) Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.

d) Analyze situations in which an object 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, in situations such as the following:

   1) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).

   2) Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).

2. Torque and rotational statics

a) Students should understand the concept of torque, so they can:

   1) Calculate the magnitude and direction of the torque associated with a given force.

   2) Calculate the torque on a rigid object due to gravity.

b) Students should be able to analyze problems in statics, so they can:

   1) State the conditions for translational and rotational equilibrium of a rigid object.

   2) Apply these conditions in analyzing the equilibrium of a rigid object under the combined influence of a number of coplanar forces applied at different locations.

c) Students should develop a qualitative understanding of rotational inertia, so they can:

   1) Determine by inspection which of a set of symmetrical objects of equal mass has the greatest rotational inertia.

   2) Determine by what factor an object's rotational inertia changes if all its dimensions are increased by the same factor.

d) Students should develop skill in computing rotational inertia so they can find the rotational inertia of:

   1) A collection of point masses lying in a plane about an axis perpendicular to the plane.

   2) A thin rod of uniform density, about an arbitrary axis perpendicular to the rod.

   3) A thin cylindrical shell about its axis, or an object that may be viewed as being made up of coaxial shells.

e) Students should be able to state and apply the parallel-axis theorem.

3. Rotational kinematics and dynamics

a) Students should 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 an object that rotates about a fixed axis with constant angular acceleration.

b) Students should be able to use the right-hand rule to associate an angular velocity vector with a rotating object.

c) Students should understand the dynamics of fixed-axis rotation, so they can:

   1) Describe in detail the analogy between fixed-axis rotation and straight-line translation.

   2) Determine the angular acceleration with which a rigid object is accelerated about a fixed axis when subjected to a specified external torque or force.

   3) Determine the radial and tangential acceleration of a point on a rigid object.

   4) Apply conservation of energy to problems of fixed-axis rotation.

   5) Analyze problems involving strings and massive pulleys.

d) Students should understand the motion of a rigid object along a surface, so they can:

   1) Write down, justify and apply the relation between linear and angular velocity, or between linear and angular acceleration, for an object of circular cross-section that rolls without slipping along a fixed plane, and determine the velocity and acceleration of an arbitrary point on such an object.

   2) Apply the equations of translational and rotational motion simultaneously in analyzing rolling with slipping.

   3) Calculate the total kinetic energy of an object that is undergoing both translational and rotational motion, and apply energy conservation in analyzing such motion.

4. Angular momentum and its conservation

a) Students should be able to use the vector product and the right-hand rule, so they can:

   1) Calculate the torque of a specified force about an arbitrary origin.

   2) Calculate the angular momentum vector for a moving particle.

   3) Calculate the angular momentum vector for a rotating rigid object in simple cases where this vector lies parallel to the angular velocity vector.

b) Students should understand angular momentum conservation, so they can:

   1) Recognize the conditions under which the law of conservation is applicable and relate this law to one- and two-particle systems such as satellite orbits.

   2) State the relation between net external torque and angular momentum, and identify situations in which angular momentum is conserved.

   3) Analyze problems in which the moment of inertia of an object is changed as it rotates freely about a fixed axis.

4) Analyze a collision between a moving particle and a rigid object that can rotate about a fixed axis or about its center of mass.

F. Oscillations and Gravitation

1. Simple harmonic motion (dynamics and energy relationships)

Students should understand simple harmonic motion, so they can:

a) Sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period and frequency of the motion.

b) Write down an appropriate expression for displacement of the form $A\sin(\omega t)$ or $A\cos(\omega t)$ to describe the motion.

c) Find an expression for velocity as a function of time.

d) State the relations between acceleration, velocity and displacement, and identify points in the motion where these quantities are zero or achieve their greatest positive and negative values.

e) State and apply the relation between frequency and period.

f) Recognize that a system that obeys a differential equation of the form $d^2x/dt^2 = -\omega^2 x$ must execute simple harmonic motion, and determine the frequency and period of such motion.

g) State how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic.

h) Calculate the kinetic and potential energies of an oscillating system as functions of time, sketch or identify graphs of these functions, and prove that the sum of kinetic and potential energy is constant.

i) Calculate the maximum displacement or velocity of a particle that moves in simple harmonic motion with specified initial position and velocity.

j) Develop a qualitative understanding of resonance so they can identify situations in which a system will resonate in response to a sinusoidal external force.

2. Mass on a spring

Students should be able to apply their knowledge of simple harmonic motion to the case of a mass on a spring, so they can:

a) Derive the expression for the period of oscillation of a mass on a spring.

b) Apply the expression for the period of oscillation of a mass on a spring.

c) Analyze problems in which a mass hangs from a spring and oscillates vertically.

d) Analyze problems in which a mass attached to a spring oscillates horizontally.

e) Determine the period of oscillation for systems involving series or parallel combinations of identical springs, or springs of differing lengths.

3. **Pendulum and other oscillations**

   Students should be able to apply their knowledge of simple harmonic motion to the case of a pendulum, so they can:

   a) Derive the expression for the period of a simple pendulum.

   b) Apply the expression for the period of a simple pendulum.

   c) State what approximation must be made in deriving the period.

   d) Analyze the motion of a torsional pendulum or physical pendulum in order to determine the period of small oscillations.

4. **Newton's law of gravity**

   Students should know Newton's law of universal gravitation, so they can:

   a) Determine the force that one spherically symmetrical mass exerts on another.

   b) Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.

   c) Describe the gravitational force inside and outside a uniform sphere, and calculate how the field at the surface depends on the radius and density of the sphere.

5. **Orbits of planets and satellites**

   Students should understand the motion of an object in orbit under the influence of gravitational forces, so they can:

   a) For a circular orbit:

      1) Recognize that the motion does not depend on the object's mass; describe qualitatively how the velocity, period of revolution and centripetal acceleration depend upon the radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit.

      2) Derive Kepler's third law for the case of circular orbits.

      3) Derive and apply the relations among kinetic energy, potential energy and total energy for such an orbit.

   b) For a general orbit:

      1) State Kepler's three laws of planetary motion and use them to describe in qualitative terms the motion of an object in an elliptical orbit.

      2) Apply conservation of angular momentum to determine the velocity and radial distance at any point in the orbit.

      3) Apply angular momentum conservation and energy conservation to relate the speeds of an object at the two extremes of an elliptical orbit.

      4) Apply energy conservation in analyzing the motion of an object that is projected straight up from a planet's surface or that is projected directly toward the planet from far above the surface.