

# Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>I. NEWTONIAN MECHANICS</b>	✓	✓
<b>A. Kinematics</b>	✓	✓
<b>1. Motion in One Dimension</b>		
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 that 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 $v = v_0 + at$ , $s_0 = s_0 + v_0 t + at^2/2$ , and $v^2 - v_0^2 = 2a(s - s_0)$ 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 $dv/dt = f(v) g(t)$ and solve it for $v(t)$ , incorporating correctly a given initial value of $v$ .		✓
<b>2. Motion in Two Dimensions</b>		
a) Students should know how to deal with displacement and velocity vectors so they can:		
(1) Relate velocity, displacement, and time for motion with constant velocity.	✓	✓

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(2) Calculate the component of a vector along a specified axis, or resolve a vector into components along two specified mutually perpendicular axes.	✓	✓
(3) Add vectors in order to find the net displacement of a particle that undergoes successive straight-line displacements.	✓	✓
(4) Subtract displacement vectors in order to find the location of one particle relative to another, or calculate the average velocity of a particle.	✓	✓
(5) Add or subtract velocity vectors in order to calculate the velocity change or average acceleration 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 above level ground with a specified initial velocity.	✓	✓
<b>B. Newton's Laws of Motion</b>	✓	✓
<b>1. Static Equilibrium (First Law)</b>		
a) 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.	✓	✓
<b>2. Dynamics of a Single Particle (Second Law)</b>		
a) Students should understand the relation between the force that acts on a body and the resulting change in the body's velocity so they can:		
(1) Calculate, for a body moving in one direction, the velocity change that results when a constant force $F$ acts over a specified time interval.	✓	✓
(2) Calculate, for a body moving in one dimension, the velocity change that results when a force $F(t)$ acts over a specified time interval.		✓

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(3) Determine, for a body moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the body.	✓	✓
b) Students should understand how Newton's Second Law, $\mathbf{F} = m\mathbf{a}$ , applies to a body subject to forces such as gravity, the pull of strings, or contact forces, so they can:		
(1) Draw a well-labeled diagram showing all real forces that act on the body.	✓	✓
(2) Write down the vector equation that results from applying Newton's Second Law to the body, and take components of this equation along appropriate axes.	✓	✓
c) Students should be able to 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, in situations such as the following:		
(1) Motion up or down with constant acceleration (in an elevator, for example).	✓	✓
(2) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).	✓	✓
(3) 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).	✓	✓
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 a body slides down a rough inclined plane or is pulled or pushed across a rough surface.	✓	✓
(3) Analyze static situations involving friction to determine under what circumstances a body will start to slip, or to calculate the magnitude of the force of static friction.	✓	✓
e) Students should understand the effect of fluid friction on the motion of a body so they can:		

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(1) Find the terminal velocity of a body moving vertically through a fluid that exerts a retarding force proportional to 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.		✓
<b>3. Systems of Two or More Bodies (Third Law)</b>		
a) Students should 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.	✓	✓
b) Students should be able to apply Newton's Third Law in analyzing the force of contact between two bodies 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 bodies 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.		✓
<b>C. Work, Energy, and Power</b>	✓	✓
<b>1. Work and the Work-Energy Theorem</b>		
a) Students should understand the definition of work so they can:		
(1) Calculate the work done by a specified constant force on a body 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 $F(x)$ on a body that undergoes a specified displacement in one dimension.		✓
(4) Use the scalar product operation to calculate the work performed by a specified constant force $F$ on a body that undergoes a displacement in a plane.	✓	✓

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b) Students should understand the work-energy theorem so they can:		
(1) State the theorem precisely, and prove it for the case of motion in one dimension.		✓
(2) Calculate the change in kinetic energy or speed that results from performing a specified amount of work on a body.	✓	✓
(3) Calculate the work performed by the net force, or by each of the forces that makes up the net force, on a body that undergoes a specified change in speed or kinetic energy.	✓	✓
(4) Apply the theorem to determine the change in a body's kinetic energy and speed that results from the application of specified forces, or to determine the force that is required in order to bring a body to rest in a specified distance.	✓	✓
<b>2. Conservative Forces and Potential Energy</b>		
a) Students should understand the concept of a conservative force so they can:		
(1) State two alternative definitions of "conservative force" and explain why these definitions are equivalent.		✓
(2) Describe two examples each 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 $F(x)$ .		✓
(3) Given the potential energy function $U(x)$ for a one-dimensional force, calculate the magnitude and direction of the force.		✓
(4) Write an expression for the force exerted by an ideal spring and for the potential energy stored in a stretched or compressed spring.	✓	✓
(5) Calculate the potential energy of a single body in a uniform gravitational field.	✓	✓
(6) Calculate the potential energy of a system of bodies in a uniform gravitational field.		✓

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(7) State the generalized work-energy theorem and use it to relate the work done by non-conservative forces on a body to the changes in kinetic and potential energy of the body.		✓
<b>3. Conservation of Energy</b>		
a) Students should understand the concepts of mechanical energy and of total energy so they can:		
(1) State, prove, and apply the relation between the work performed on a body by non-conservative forces and the change in a body's mechanical energy.		✓
(2) Describe and identify situations in which mechanical energy is converted to other forms of energy.		✓
(3) Analyze situations in which a body'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 bodies that are moving in a gravitational field and are subject to constraints imposed by strings or surfaces.	✓	✓
(3) Apply conservation of energy in analyzing the motion of bodies that move under the influence of springs.	✓	✓
(4) Apply conservation of energy in analyzing the motion of bodies that move under the influence of other specified 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.		✓
<b>4. Power</b>		
a) Students should understand the definition of power so they can:		
(1) Calculate the power required to maintain the motion of a body with constant acceleration (e.g., to move a body along a level surface, to raise a body at a constant rate, or to overcome friction for a body that is moving at a constant speed).	✓	✓

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(2) 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.	✓	✓
(3) Prove that the relation $P = \mathbf{F} \cdot \mathbf{v}$ follows from the definition of work, and apply this relation in analyzing particle motion.		✓
<b>D. Systems of Particles, Linear Momentum</b>	✓	✓
<b>1. Center of Mass</b>		
a) Students should understand the technique for finding center of mass so they can:		
(1) Identify by inspection the center of mass of a body that has a point of symmetry.		✓
(2) Locate the center of mass of a system consisting of two such bodies.		✓
(3) Use integration to find the center of mass of a thin rod of non-uniform density, of a plane lamina of uniform density, or of a solid of revolution of uniform density.		✓
b) Students should be able to 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.		✓
c) Students should be able to 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.		✓
<b>2. Impulse and Momentum:</b> Students should understand impulse and linear momentum so they can:		
a) Relate mass, velocity, and linear momentum for a moving body, and calculate the total linear momentum of a system of bodies.	✓	✓
b) Relate impulse to the change in linear momentum and the average force acting on a body.	✓	✓
c) State and apply the relations between linear momentum and center-of-mass motion for a system of particles.		✓
d) Define impulse, and prove and apply the relation between impulse and momentum.		✓

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<b>3. Conservation of Linear Momentum, Collisions</b>		
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 determine the final velocity when two bodies that are moving along the same line, or at right angles, collide and stick together, and calculate how much kinetic energy is lost in such a situation.	✓	✓
(4) Analyze collisions of particles in one or two dimensions to determine unknown masses or velocities, and calculate how much kinetic energy is lost in a collision.	✓	✓
(5) Analyze situations in which two bodies 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 a particle relative to a moving medium such as a flowing stream.		✓
(2) Transform the description of a collision or decay process to or from a frame of reference in which the center of mass of the system is at rest.		✓
(3) Analyze the motion of particles relative to a frame of reference that is accelerating horizontally or vertically at a uniform rate.		✓
<b>E. Circular Motion and Rotation</b>	✓	✓
<b>1. Uniform Circular Motion:</b> 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.	✓	✓



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c) Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.	✓	✓
<b>2. Angular Momentum and Its Conservation</b>		
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 body 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 a body is changed as it rotates freely about a fixed axis.		✓
(4) Analyze a collision between a moving particle and a rigid body that can rotate about a fixed axis or about its center of mass.		✓
<b>3. Torque and Rotational Statics</b>	✓	✓
a) Students should understand the concept of torque so they can:		
(1) Calculate the magnitude and sense of the torque associated with a given force.	✓	✓
(2) Calculate the torque on a rigid body 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 body.	✓	✓
(2) Apply these conditions in analyzing the equilibrium of a rigid body under the combined influence of a number of coplanar forces applied at different locations.	✓	✓

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c) Students should develop a qualitative understanding of rotational inertia so they can:		
(1) Determine by inspection which of a set of symmetric bodies of equal mass has the greatest rotational inertia.		✓
(2) Determine by what factor a body'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 a body that may be viewed as being made up of coaxial shells.		✓
(4) A solid sphere of uniform density about an axis through its center.		✓
<b>4. Rotational Kinematics and Dynamics</b>		
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 a body 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 body.		✓
c) Students should be able to state and apply the parallel-axis theorem.		✓
d) 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 body is accelerated about a fixed axis when subjected to a specified external torque or force.		✓

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(3) Apply conservation of energy to problems of fixed-axis rotation.		✓
(4) Analyze problems involving strings and massive pulleys.		✓
e) Students should understand the motion of a rigid body 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 a body of circular cross-section that rolls without slipping along a fixed plane, and determine the velocity and acceleration of an arbitrary point on such a body.		✓
(2) Apply the equations of translational and rotational motion simultaneously in analyzing rolling with slipping.		✓
(3) Calculate the total kinetic energy of a body that is undergoing both translational and rotational motion, and apply energy conservation in analyzing such motion.		✓
<b>F. Oscillations</b>	✓	✓
<b>1. Students should understand the kinematics of simple harmonic motion so they can:</b>		
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) Identify points in the motion where the velocity is zero or achieves its maximum positive or negative value.	✓	✓
d) Find an expression for velocity as a function of time		✓
e) State qualitatively the relation between acceleration and displacement.	✓	✓
f) Identify points in the motion where the acceleration is zero or achieves its greatest positive or negative value.	✓	✓
g) State and prove the relation between acceleration and displacement.		✓
h) State and apply the relation between frequency and period.	✓	✓

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i) Recognize that a system that obeys a differential equation of the form $d^2x/dt^2 = -kx$ must execute simple harmonic motion, and determine the frequency and period of such motion.		✓
j) 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.	✓	✓
k) 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.	✓	✓
l) Calculate the maximum displacement or velocity of a particle that moves in simple harmonic motion with specified initial position and velocity.		✓
m) Develop a qualitative understanding of resonance so they can identify situations in which a system will resonate in response to a sinusoidal external force.		✓
<b>2. Students should be able to apply their knowledge of simple harmonic motion to the case of a mass on a spring, so they can:</b>		
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.		✓
<b>3. Students should be able to apply their knowledge of simple harmonic motion to the case of a pendulum, so they can:</b>		
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.		✓

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<b>G. Gravitation</b>	✓	✓
<b>1. Students should know Newton's Law of Universal Gravitation</b> 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.		✓
<b>2. Students should understand the motion of a body in orbit under the influence of gravitational forces</b> so they can:		
a) For a circular orbit:		
(1) 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 radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit.	✓	✓
(2) Prove that Kepler's Third Law must hold for this special case.		✓
(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 a body in an elliptic 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 a body at the two extremes of an elliptic orbit.	✓	✓
(4) 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.		✓

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<b>II. HEAT, KINETIC THEORY, AND THERMODYNAMICS</b>	✓	
<b>A. Fluid Mechanics</b>		
<b>1. Hydrostatic Pressure</b>		
a) Students should understand that a fluid exerts pressure in all directions	✓	
b) Students should understand that a fluid at rest exerts pressure perpendicular to any surface that it contacts	✓	
c) Students should understand and be able to use the relationship between pressure and depth in a liquid, $\Delta p = \rho g \Delta h$ .	✓	
<b>2. Buoyancy</b>		
a) Students should understand that the difference in the pressure on the upper and lower surfaces of an object immersed in liquid results in an upward force on the object.	✓	
b) Students should understand and be able to apply Archimedes' principle: the buoyant force on a submersed object is equal to the weight of the liquid it displaces.	✓	
<b>3. Fluid flow continuity</b>		
a) Students should understand that for laminar flow, the flow rate of a liquid through its cross section is the same at any point along its path.	✓	
b) Students should understand and be able to apply the equation of continuity, $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$ .	✓	
<b>4. Bernoulli's Equation</b>		
a) Students should understand that the pressure of a flowing liquid is low where the velocity is high, and vice versa.	✓	
b) Students should understand and be able to apply Bernoulli's equation, $p + \frac{1}{2} \rho v^2 + \rho g y = \text{constant}$ .	✓	

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<b>B. Temperature and Heat</b>		
1. Students should understand the “mechanical equivalent of heat” so they can calculate how much a substance will be heated by the performance of a specified quantity of mechanical work.	✓	
2. Students should understand the concepts of specific heat, heat of fusion, and heat of vaporization so they can:		
a) Identify, given a graph relating the quantity of heat added to a substance and its temperature, the melting point, and boiling point and determine the heats of fusion and vaporization and the specific heat of each phase.	✓	
b) Determine how much heat must be added to a sample of a substance to raise its temperature from one specified value to another, or to cause it to melt or vaporize.	✓	
3. Students should understand heat transfer and thermal expansion so they can:		
a) Determine the final temperature achieved when substances, all at different temperatures, are mixed and allowed to come to thermal equilibrium.	✓	
b) Calculate how the flow of heat through a slab of material is affected by changes in the thickness or area of the slab, or the temperature difference between the two faces of the slab.	✓	
c) Analyze qualitatively what happens to the size and shape of a body when it is heated.	✓	
<b>C. Kinetic Theory and Thermodynamics</b>	✓	
<b>1. Ideal Gases</b>		
a) Students should understand the kinetic theory model of an ideal gas so they can:		
(1) State the assumptions of the model.	✓	
(2) State the connection between temperature and mean translational kinetic energy, and apply it to determine the mean speed of gas molecules as a function of their mass and the temperature of the gas.	✓	
(3) State the relationship among Avogadro’s number, Boltzmann’s constant, and the gas constant $R$ , and express the energy of a mole of a monatomic ideal gas as a function of its temperature.	✓	

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(4) Explain qualitatively how the model explains the pressure of a gas in terms of collisions with the container walls, and explain how the model predicts that, for fixed volume, pressure must be proportional to temperature.	✓	
b) Students should know how to apply the ideal gas law and thermodynamic principles so they can:		
(1) Relate the pressure and volume of a gas during an isothermal expansion or compression.	✓	
(2) Relate the pressure and temperature of a gas during constant-volume heating or cooling, or the volume and temperature during constant-pressure heating or cooling.	✓	
(3) Calculate the work performed on or by a gas during an expansion or compression at constant pressure.	✓	
(4) Understand the process of adiabatic expansion or compression of a gas.	✓	
(5) Identify or sketch on a $pV$ diagram the curves that represent each of the above processes.	✓	
<b>2. Laws of Thermodynamics</b>		
a) Students should know how to apply the first law of thermodynamics so they can:		
(1) Relate the heat absorbed by a gas, the work performed by the gas, and the internal energy change of the gas for any of the processes above.	✓	
(2) Relate the work performed by a gas in a cyclic process to the area enclosed by a curve on a $pV$ diagram.	✓	
b) Students should understand the second law of thermodynamics, the concept of entropy, and heat engines and the Carnot cycle so they can:		
(1) Determine whether entropy will increase, decrease, or remain the same during a particular situation.	✓	
(2) Compute the maximum possible efficiency of a heat engine operating between two given temperatures.	✓	



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(3) Compute the actual efficiency of a heat engine.	✓	
(4) Relate the heats exchanged at each thermal reservoir in a Carnot cycle to the temperatures of the reservoirs.	✓	
<b>III. ELECTRICITY AND MAGNETISM</b>	✓	✓
<b>A. Electrostatics</b>	✓	✓
<b>1. Charge, Field, and Potential</b>		
a) Students should understand the concept of electric field so they can:		
(1) Define it in terms of the force on a test charge.	✓	✓
(2) Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field.	✓	✓
(3) Calculate the net force and torque on a collection of charges in an electric field.		✓
(4) Given a diagram on which an electric field is represented by flux lines, determine the direction of the field at a given point, identify locations where the field is strong and where it is weak, and identify where positive or negative charges must be present.	✓	✓
(5) Analyze the motion of a particle of specified charge and mass in a uniform electric field.	✓	✓
b) Students should understand the concept of electric potential so they can:		
(1) Calculate the electrical work done on a positive or negative charge that moves through a specified potential difference.	✓	✓
(2) Given a sketch of equipotentials for a charge configuration, determine the direction and approximate magnitude of the electric field at various positions.	✓	✓
(3) Apply conservation of energy to determine the speed of a charged particle that has been accelerated through a specified potential difference.	✓	✓
(4) Calculate the potential difference between two points in a uniform electric field, and state which is at the higher potential.	✓	✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
(5) Given electric field strength as a function of position along a line, use integration to determine electric potential as a function of position.		✓
(6) State the general relationship between field and potential, and define and apply the concept of a conservative electric field.		✓
<b>2. Coulomb's Law and Field and Potential of Point Charges</b>		
a) Students should understand Coulomb's Law and the principle of superposition so they can:		
(1) Determine the force that acts between specified point charges, and describe the electric field of a single point charge.	✓	✓
(2) Use vector addition to determine the electric field produced by two or more point charges.	✓	✓
b) Students should know the potential function for a point charge so they can:		
(1) Determine the electric potential in the vicinity of one or more point charges.	✓	✓
(2) Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges.		✓
(3) Calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to move a set of charges into a new configuration.		✓
<b>3. Fields and Potentials of Other Charge Distributions</b>		
a) Students should be able to use the principle of superposition to calculate by integration:		
(1) The electric field of a straight, uniformly charged wire.		✓
(2) The electric field and potential of a thin ring of charge on the axis of the ring, or of a semicircle of charge at its center.		✓
(3) The electric potential of a uniformly charged disk on the axis of the disk.		✓

# Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
b) Students should know the fields of highly symmetric charge distributions so they can:		
(1) Identify situations in which the direction of the electric field produced by a charge distribution can be deduced from symmetry considerations.		✓
(2) Describe the electric field of:		
(a) Parallel charged plates.	✓	✓
(b) A long uniformly charged wire or thin cylindrical shell.		✓
(c) A thin spherical shell.		✓
(3) Use superposition to determine the fields of parallel charged planes, coaxial cylinders, or concentric spheres.		✓
(4) Derive expressions for electric potential as a function of position in the above cases.		✓
<b>4. Gauss's Law</b>		
a) Students should understand the relationship between field and flux so they can:		
(1) Calculate the flux of a uniform electric field $E$ through an arbitrary surface.		✓
(2) Calculate the flux of $E$ through a curved surface when $E$ is uniform in magnitude and perpendicular to the surface.		✓
(3) Calculate the flux of $E$ through a rectangle when $E$ is perpendicular to the rectangle and a function of one coordinate only.		✓
(4) State and apply the relationship between flux and lines of force.		✓
b) Students should understand Gauss's Law so they can:		
(1) State the law in integral form, and apply it qualitatively to relate flux and electric charge for a specified surface.		✓
(2) Apply the law, along with symmetry arguments, to determine the electric field near a large uniformly charged plane, inside or outside a uniformly charged long cylinder or cylindrical shell, and inside or outside a uniformly charged sphere or spherical shell.		✓
(3) Apply the law to determine the charge density or total charge on a surface in terms of the electric field near the surface.		✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
(4) Graph the electric field and potential function by the calculus method of finding maxima and minima.		✓
<b>B. Conductors, Capacitors, Dielectrics</b>	✓	✓
<b>1. Electrostatics with Conductors</b>		
a) Students should understand the nature of electric fields in and around conductors so they can:		
(1) Explain the mechanics responsible for the absence of electric field inside a conductor, and why all excess charge must reside on the surface of the conductor.	✓	✓
(2) Explain why a conductor must be an equipotential, and apply this principle in analyzing what happens when conductors are connected by wires.	✓	✓
(3) Determine the direction of the force on a charged particle brought near an uncharged or grounded conductor.	✓	✓
(4) Prove that all excess charge on a conductor must reside on its surface and that the field outside the conductor must be perpendicular to the surface.		✓
(5) Prove and apply the relationship between the surface charge density on a conductor and the electric field strength near its surface.		✓
b) Students should be able to describe and sketch a graph of the electric field and potential inside and outside a charged conducting sphere.	✓	✓
c) Students should understand induced charge and electrostatic shielding so they can:		
(1) Describe qualitatively the process of charging by induction.	✓	✓
(2) Determine the direction of the force on a charged particle brought near an uncharged or grounded conductor.	✓	✓
(3) Explain qualitatively why there can be no electric field in a charge-free region completely surrounded by a single conductor, and recognize consequences of this result.		✓
(4) Explain qualitatively why the electric field outside a closed conducting surface cannot depend on the precise location of charge in the space enclosed by the conductor, and identify consequences of this result.		✓

# Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>2. Capacitors</b>		
a) Students should know the definition of capacitance so they can relate stored charge and voltage for a capacitor.	✓	✓
b) Students should understand energy storage in capacitors so they can:		
(1) Relate voltage, charge, and stored energy for a capacitor.	✓	✓
(2) Recognize situations in which energy stored in a capacitor is converted to other forms.	✓	✓
c) Students should understand the physics of the parallel-plate capacitor so they can:		
(1) Describe the electric field inside the capacitor, and relate the strength of this field to the potential difference between the plates and the plate separation.	✓	✓
(2) Relate the electric field to the density of the charge on the plates.		✓
(3) Derive an expression for the capacitance of a parallel-plate capacitor.		✓
(4) Determine how changes in dimension will affect the value of the capacitance.	✓	✓
(5) Derive and apply expressions for the energy stored in a parallel-plate capacitor and for the energy density in the field between the plates.		✓
(6) Analyze situations in which capacitor plates are moved apart or moved closer together, or in which a conducting slab is inserted between capacitor plates, either with a battery connected between the plates or with the charge on the plates held fixed.		✓
d) Students should understand cylindrical and spherical capacitors so they can:		
(1) Describe the electric field inside each.		✓
(2) Derive an expression for the capacitance of each.		✓
<b>3. Dielectrics - Students should understand the behavior of dielectrics so they can:</b>		
a) Describe how the insertion of a dielectric between the plates of a charged parallel-plate capacitor affects its capacitance and the field strength and voltage between the plates.		✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
b) Analyze situations in which a dielectric slab is inserted between the plates of a capacitor.		✓
<b>C. Electric Circuits</b>	✓	✓
<b>1. Current, Resistance, Power</b>		
a) Students should 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.	✓	✓
b) Students should understand conductivity, resistivity, and resistance so they can:		
(1) Relate current and voltage for a resistor.	✓	✓
(2) Write the relationship between electric field strength and current density in a conductor, and describe qualitatively, in terms of the drift velocity of electrons, why such a relationship is plausible.		✓
(3) Describe how the resistance of a resistor depends upon its length and cross-sectional area.	✓	✓
(4) Derive an expression for the resistance of a resistor of uniform cross-section in terms of its dimensions and the conductivity of the material from which it is constructed, and apply this result in comparing current flow in resistors of different material or different geometry.		✓
(5) Derive expressions that relate the current, voltage, and resistance to the rate at which heat is produced when current passes through a resistor.		✓
(6) Apply the relationships for the rate of heat production in a resistor.	✓	✓
<b>2. Steady-State Direct Current Circuits with Batteries and Resistors Only</b>		
a) Students should understand the behavior of series and parallel combinations of resistors so they can:		
(1) Identify on a circuit diagram whether resistors are in series or in parallel.	✓	✓
(2) Determine the ratio of the voltages across resistors connected in series or the ratio of the currents through resistors connected in parallel.	✓	✓

# Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
(3) Calculate the equivalent resistance of two or more resistors connected in series or in parallel, or of a network of resistors that can be broken down into series and parallel combinations.	✓	✓
(4) Calculate the voltage, current, and power dissipation for any resistor in such a network of resistors connected to a single battery.	✓	✓
(5) Design a simple series-parallel circuit that produces a given current and terminal voltage for one specified component, and draw a diagram for the circuit using conventional symbols.	✓	✓
b) Students should understand the properties of ideal and real batteries so they can:		
(1) Calculate the terminal voltage of a battery of specified emf and internal resistance from which a known current is flowing.	✓	✓
(2) Calculate the rate at which a battery is supplying energy to a circuit or is being charged up by a circuit.		✓
(3) State what external resistance draws maximum power from a battery of specified internal resistance, and apply this result in solving problems involving one or more resistors connected to a single battery.		✓
c) Students should be able to apply Ohm's Law and Kirchhoff's rules to direct-current circuits in order to:		
(1) Determine a single unknown current, voltage, or resistance.	✓	✓
(2) Set up and solve simultaneous equations to determine two unknown currents.		✓
d) Students should understand the properties of voltmeters and ammeters so they can:		
(1) State whether the resistance of each is high or low.	✓	✓
(2) Identify or show correct methods of connecting meters into circuits in order to measure voltage or current.	✓	✓
(3) Assess qualitatively the effect of finite meter resistance on a circuit into which these meters are connected.		✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>3. Capacitors in Circuits</b>		
a) Students should understand the behavior of capacitors connected in series or in parallel so they can:		
(1) Calculate the equivalent capacitance of a series or parallel combination.	✓	✓
(2) Describe how stored charge is divided between two capacitors connected in parallel.	✓	✓
(3) Determine the ratio of voltages for two capacitors connected in series.	✓	✓
b) Students should understand energy storage in capacitors so they can:		
(1) Relate voltage, charge, and stored energy for a capacitor.		✓
(2) Recognize situations in which energy stored in a capacitor is converted to other forms.		✓
c) Students should be able to calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors.	✓	✓
d) Students should understand the discharging or charging of a capacitor through a resistor so they can:		
(1) Calculate and interpret the time constant of the circuit.		✓
(2) Sketch or identify graphs of stored charge or voltage for the capacitor, or of current or voltage for the resistor, and indicate on the graph the significance of the time constant.		✓
(3) Write expressions to describe the time dependence of the stored charge or voltage for the capacitor, or of the current or voltage for the resistor.		✓
e) Students should develop skill in analyzing the behavior of circuits containing several capacitors and resistors so they can:		
(1) Determine voltages and currents immediately after a switch has been closed and also after steady-state conditions have been established.	✓	✓
(2) Identify graphs that correctly indicate how voltages and currents vary with time.		✓



## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>D. Magnetostatics</b>	✓	✓
<b>1. Forces on Moving Charges in Magnetic Fields</b>		
a) Students should understand the force experienced by a charged particle in a magnetic field so they can:		
(1) Calculate the magnitude and direction of the force in terms of $q$ , $\mathbf{v}$ , and $\mathbf{B}$ , and explain why the magnetic force can perform no work.	✓	✓
(2) Deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field.	✓	✓
(3) State and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field, and derive this formula from Newton's Second Law and the magnetic force law.	✓	✓
(4) Describe the most general path possible for a charged particle moving in a uniform magnetic field, and describe the motion of a particle that enters a uniform magnetic field moving with specified initial velocity.	✓	✓
(5) Describe quantitatively under what conditions particles will move with constant velocity through crossed electric and magnetic fields.	✓	✓
<b>2. Forces on Current-carrying Wires in Magnetic Fields</b>		
(a) Students should understand the force experienced by a current in a magnetic field so they can:		
(1) Calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field.	✓	✓
(2) Indicate the direction of magnetic forces on a current-carrying loop of wire in a magnetic field, and determine how the loop will tend to rotate as a consequence of these forces.	✓	✓
(3) Calculate the magnitude and direction of the torque experienced by a rectangular loop of wire carrying a current in a magnetic field.		✓
<b>3. Fields of Long Current-carrying Wires</b>		
a) Students should understand the magnetic field produced by a long straight current-carrying wire so they can:		
(1) Calculate the magnitude and direction of the field at a point in the vicinity of such a wire.	✓	✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
(2) Use superposition to determine the magnetic field produced by two long wires.	✓	✓
(3) Calculate the force of attraction or repulsion between two long current-carrying wires.	✓	✓
<b>4. The Biot-Savart Law and Ampere's Law</b>		
a) Students should understand the Biot-Savart Law so they can:		
(1) Deduce the magnitude and direction of the contribution to the magnetic field made by a short straight segment of current-carrying wire.		✓
(2) Derive and apply the expression for the magnitude of $\mathbf{B}$ on the axis of a circular loop of current.		✓
b) Students should understand the statement and application of Ampere's Law in integral form so they can:		
(1) State the law precisely.		✓
(2) Use Ampere's law, plus symmetry arguments and the right-hand rule, to relate magnetic field strength to current for a long straight wire, or for a hollow or solid cylinder.		✓
c) Students should develop skill in applying the superposition principle so they can determine the magnetic field produced by combinations of the configurations listed above.		✓
<b>E. Electromagnetism</b>	✓	✓
<b>1. Electromagnetic Induction</b>		
a) Students should understand the concept of magnetic flux so they can:		
(1) Calculate the flux of a uniform magnetic field through a loop of arbitrary orientation.	✓	✓
(2) Use integration to calculate the flux of a non-uniform magnetic field, whose magnitude is a function of one coordinate, through a rectangular loop perpendicular to the field.		✓
b) Students should understand Faraday's Law and Lenz's Law so they can:		
(1) Recognize situations in which changing flux through a loop will cause an induced emf or current in the loop.	✓	✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
(2) Calculate the magnitude and direction of the induced emf and current in:		
(a) A square loop of wire pulled at a constant velocity into or out of a uniform magnetic field.	✓	✓
(b) General cases of a loop of wire that is being pulled into or out of a uniform magnetic field.		✓
(c) A loop of wire placed in a spatially uniform magnetic field whose magnitude is changing at a constant rate.	✓	✓
(d) A loop of wire placed in a spatially uniform magnetic field whose magnitude is a specified function of time.		✓
(e) A loop of wire that rotates at a constant rate about an axis perpendicular to a uniform magnetic field.	✓	✓
(f) A conducting bar moving perpendicular to a uniform magnetic field.	✓	✓
c) Students should develop skill in analyzing the forces that act on induced currents so they can solve simple problems involving the mechanical consequences of electromagnetic induction.		✓
<b>2. Inductance</b> (Including <i>LR</i> and <i>LC</i> circuits)		
a) Students should understand the concept of inductance so they can:		
(1) Calculate the magnitude and sense of the emf in an inductor through which a specified changing current is flowing.		✓
(2) Derive and apply the expression for the self-inductance of a long solenoid.		✓
b) Students should develop skill in analyzing circuits containing inductors and resistors so they can write and solve the differential equation that relates current to time.		✓
<b>3. Maxwell's equations in integral form</b>		
(1) Students should be familiar with Maxwell's equations so they can associate each equation with its implications.		✓

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>IV. WAVES AND OPTICS</b>	✓	
<b>A. Wave Motion</b> (including Sound)	✓	
<b>1. Students should understand the description of traveling waves</b> so they can:		
a) Sketch or identify graphs that represent traveling waves and determine the amplitude, wavelength, and frequency of a wave from such a graph.	✓	
b) State and apply the relation among wavelength, frequency, and velocity for a wave.	✓	
c) Sketch or identify graphs that describe reflection of a wave from the fixed or free end of a string.	✓	
d) Know qualitatively what factors determine the speed of waves on a string and the speed of sound.	✓	
<b>2. Students should understand the physics of standing waves</b> so they can:		
a) Sketch possible standing wave modes for a stretched string that is fixed at both ends, and determine the amplitude, wavelength, and frequency of such standing waves.	✓	
b) Describe possible standing sound waves in a pipe that has either open or closed ends, and determine the wavelength and frequency of such standing waves.	✓	
<b>3. Students should understand the Doppler effect for sound</b> so they can:		
a) Explain the mechanism that gives rise to a frequency shift in both the moving-source and moving-observer case, and derive an expression for the frequency heard by the observer.	✓	
b) Write and apply the equations that describe the moving-source and moving-observer Doppler effect, and sketch or identify graphs that describe the effect.	✓	
<b>4. Students should understand the principle of superposition</b> so they can apply it to traveling waves moving in opposite directions, and describe how a standing wave may be formed by superposition.	✓	

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>B. Physical Optics</b>	✓	
1. Students should understand the interference and diffraction of waves so they can:		
a) Apply the principles of interference to coherent sources oscillating in phase in order to:		
(1) Describe the conditions under which the waves reaching an observation point from two or more sources will all interfere constructively, or under which the waves from two sources will interfere destructively.	✓	
(2) Determine locations of interference maxima or minima for two sources or determine the frequencies or wavelengths that can lead to constructive or destructive interference at a certain point.	✓	
(3) Relate the amplitude and intensity produced by two or more sources that interfere constructively to the amplitude and intensity produced by a single source.	✓	
b) Apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffraction grating so they can:		
(1) Sketch or identify the intensity pattern that results when monochromatic waves pass through a single slit and fall on a distant screen, and describe how this pattern will change if the slit width or the wavelength of the waves is changed.	✓	
(2) Calculate, for a single-slit pattern, the angles or the positions on a distant screen where the intensity is zero.	✓	
(3) Sketch or identify the intensity pattern that results when monochromatic waves pass through a double slit, and identify which features of the pattern result from single-slit diffraction and which from two-slit interference.	✓	
(4) Calculate, for a two-slit interference pattern, the angles or the positions on a distant screen at which intensity maxima or minima occur.	✓	
(5) Describe or identify the interference pattern formed by a grating of many equally spaced narrow slits, calculate the location of intensity maxima, and explain qualitatively why a multiple-slit grating is better than a two-slit grating for making accurate determinations of wavelength.	✓	

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
c) Apply the principles of interference to light reflected by thin films so they can:		
(1) State under what conditions a phase reversal occurs when light is reflected from the interface between two media of different indices of refraction.	✓	
(2) Determine whether rays of monochromatic light reflected from two such interfaces will interfere constructively or destructively, and thereby account for Newton's rings and similar phenomena, and explain how glass may be coated to minimize reflection of visible light.	✓	
<b>2. Students should understand dispersion and the electromagnetic spectrum</b> so they can:		
a) Relate a variation of index of refraction with frequency to a variation in refraction.	✓	
b) Know the names associated with electromagnetic radiation and be able to arrange in order of increasing wavelength the following: visible light of various colors, ultraviolet light, infrared light, radio waves, x-rays, and gamma rays.	✓	
<b>3. Students should understand the transverse nature of light waves</b> so they can explain qualitatively why light can exhibit polarization.	✓	
<b>4. Students should understand the inverse-square law</b> so they can calculate the intensity of light at a given distance from a source of specified power and compare the intensity of light at different distances from the source.	✓	
<b>C. Geometrical Optics</b>	✓	
<b>1. Students should understand the principles of reflection and refraction</b> so they can:		
a) Determine how the speed and wavelength of light change when light passes from one medium into another.	✓	
b) Show on a diagram the directions of reflected and refracted rays.	✓	
c) Use Snell's Law to relate the directions of the incident ray and the refracted ray, and the indices of refraction of the media.	✓	
d) Identify conditions under which total internal reflection will occur.	✓	

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>2. Students should understand image formation by plane or spherical mirrors</b> so they can:		
a) Relate the focal point of a spherical mirror to its center of curvature.	✓	
b) Given a diagram of a mirror with the focal point shown, locate by ray tracing the image of a real object and determine whether the image is real or virtual, upright or inverted, enlarged or reduced in size.	✓	
<b>3. Students should understand image formation by converging or diverging lenses</b> so they can:		
a) Determine whether the focal length of a lens is increased or decreased as a result of a change in the curvature of its surfaces or in the index of refraction of the material of which the lens is made or the medium in which it is immersed.	✓	
b) Determine by ray tracing the location of the image of a real object located inside or outside the focal point of the lens, and state whether the resulting image is upright or inverted, real or virtual.	✓	
c) Use the thin lens equation to relate the object distance, image distance, and focal length for a lens, and determine the image size in terms of the object size.	✓	
d) Analyze simple situations in which the image formed by one lens serves as the object for another lens.	✓	
<b>V. MODERN PHYSICS</b>		
<b>A. Atomic Physics and Quantum Effects</b>	✓	
1. STUDENTS SHOULD BE ABLE TO DESCRIBE THE RUTHERFORD SCATTERING EXPERIMENT AND TO EXPLAIN HOW IT PROVIDES EVIDENCE FOR THE EXISTENCE OF THE ATOMIC NUCLEUS.	✓	
<b>2. Students should know the properties of photons and understand the photoelectric effect</b> so they can:		
a) Relate the energy of a photon in joules or electron-volts to its wavelength or frequency.	✓	

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
b) Relate the linear momentum of a photon to its energy or wavelength, and apply linear momentum conservation to simple processes involving the emission, absorption, or reflection of photons.	✓	
c) Calculate the number of photons per second emitted by a monochromatic source of specific wavelength and power.	✓	
d) Describe a typical photoelectric effect experiment, and explain what experimental observations provide evidence for the photon nature of light.	✓	
e) Describe qualitatively how the number of photoelectrons and their maximum kinetic energy depend on the wavelength and intensity of the light striking the surface, and account for this dependence in terms of a photon model of light.	✓	
f) When given the maximum kinetic energy of photoelectrons ejected by photons of one energy or wavelength, determine the maximum kinetic energy of photoelectrons for a different photon energy or wavelength.	✓	
g) Sketch or identify a graph of stopping potential versus frequency for a photoelectric effect experiment, determine from such a graph the threshold frequency and work function, and calculate an approximate value of $h/e$ .	✓	
<b>3. Students should understand the concept of energy levels for atoms so they can:</b>		
a) Calculate the energy or wavelength of the photon emitted or absorbed in a transition between specified levels, or the energy or wavelength required to ionize an atom.	✓	
b) Explain qualitatively the origin of emission or absorption spectra of gases.	✓	
c) Given the wavelengths or energies of photons emitted or absorbed in a two-step transition between levels, calculate the wavelength or energy for a single-step transition between the same levels.	✓	
d) Write an expression for the energy levels of hydrogen in terms of the ground-state energy, draw a diagram to depict these levels, and explain how this diagram accounts for the various "series" in the hydrogen spectrum.	✓	
e) STATE THE ASSUMPTIONS AND CONCLUSIONS FOR THE BOHR MODEL FOR THE HYDROGEN ATOM.	✓	



## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
<b>4. Students should understand the concept of DeBroglie wavelength</b> so they can:		
a) Calculate the wavelength of a particle as a function of its momentum.	✓	
b) Describe the Davisson-Germer experiment, and explain how it provides evidence for the wave nature of electrons.	✓	
<b>5. Students should understand the nature and production of x-rays</b> so they can calculate the shortest wavelength of x-rays that may be produced by electrons accelerated through a specified voltage.	✓	
<b>6. Students should understand Compton scattering</b> so they can:		
a) Describe Compton's experiment, and state what results were observed and by what sort of analysis these results may be explained.	✓	
b) Account qualitatively for the increase of photon wavelength that is observed, and explain the significance of the Compton wavelength.	✓	
<b>B. Nuclear Physics</b>	✓	
<b>1. STUDENTS SHOULD UNDERSTAND THE SIGNIFICANCE OF HALF-LIFE IN RADIOACTIVE DECAY SO THEY CAN:</b>		
a) RECOGNIZE THAT HALF-LIFE IS INDEPENDENT OF THE NUMBER OF NUCLEI PRESENT OR OF EXTERNAL CONDITIONS.	✓	
b) SKETCH OR IDENTIFY A GRAPH TO INDICATE WHAT FRACTION OF A RADIOACTIVE SAMPLE REMAINS AS A FUNCTION OF TIME, AND INDICATE THE HALF-LIFE ON SUCH A GRAPH.	✓	
c) DETERMINE, FOR AN ISOTOPE OF SPECIFIED HALF-LIFE, WHAT FRACTION OF THE NUCLEI HAVE DECAYED AFTER A GIVEN TIME HAS ELAPSED.	✓	
<b>2. Students should understand the significance of the mass number and charge of nuclei</b> so they can:		
a) Interpret symbols for nuclei that indicate these quantities.	✓	
b) Use conservation of mass number and charge to complete nuclear reactions.	✓	
c) Determine the mass number and charge of a nucleus after it has undergone specified decay processes.	✓	
d) Describe the process of $\alpha$ , $\beta$ , and $\lambda$ decay and write a reaction to describe each.	✓	

## Course Objectives for AP Physics

Objectives for the AP Physics Courses	AP Course	
	B	C
e) Explain why the existence of the neutrino had to be postulated in order to reconcile experimental data from $\beta$ decay with fundamental conservation laws.	✓	
<b>3. Students should know the nature of the nuclear force</b> so they can compare its strength and range with those of the electromagnetic force.	✓	
<b>4. Students should understand nuclear fission</b> so they can describe a typical neutron-induced fission and explain why a chain reaction is possible.	✓	
<b>5. Students should understand the relationship between mass and energy (mass-energy equivalence)</b> so they can:		
a) Qualitatively relate the energy released in nuclear processes to the change in mass.	✓	
b) Apply the relationship $E = mc^2$ in analyzing nuclear processes.	✓	