CHINO VALLEY UNIFIED SCHOOL DISTRICT
INSTRUCTIONAL GUIDE
PHYSICS B ADVANCED PLACEMENT

Course Number	5422
Department	Science
Suggested guidelines	Minimum requirements – C or better in Chemistry Concurrently enrolled/successfully completed Trigonometry/Pre-calculus
Length of Course	Two (2) semesters / One (1) year
Grade Level	11-12
Credit	5 units per semester/10 total credits - physical science
Repeatable	Not repeatable for credit
Board Approved	November 6, 2008

Description of Course - Physics Advanced Placement (AP) is the study of the physical world and deals with the behavior and structure of matter. This course provides a systematic development of the main principles of physics emphasizing problem solving and helping students develop a deep understanding of physics concepts. This course further provides study in both classical and modern physics, including Newtonian mechanics, fluid mechanics and thermal physics, electricity and magnetism, waves and optics, and atomic and nuclear physics. Students will use advanced concepts, equations and assumptions to describe the physical world and further develop their understanding of the tools of physics. This course meets the University of California laboratory science admission requirement and utilizes the AP Physics B curriculum provided by the College Board.

Rationale for Course - Physics is an elaborately integrated body of knowledge. The principles of physics come into play repeatedly in everyday life, from simple applications to understanding the laws of nature and relativity. Problem solving skills developed through the study of physics help students to improve critical thinking skills. This course is intended to be representative of courses commonly offered in colleges and universities.

Student Selection - Admission to an AP course should depend on the student interest in the subject as well as on such formal credentials as an outstanding record of academic performance. Many highly motivated students with less-than-outstanding records have successfully completed AP courses and have obtained college credit, advanced placement, or both, through an AP Examination.

Newtonian Mechanics

Standard 1 - Students will be able to understand relationships and solve problems regarding motion in one dimension.

1.1 Objective: Be able to determine the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line.

1.1.1 Performance Indicator: Using a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, students will be able to recognize in what time intervals the other two are positive, negative, or zero.

1.1.2 Performance Indicator: Using a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, students will be able to identify or sketch a graph of each as a function of time.

1.1.3 Performance Indicator: Using an expression for one of the kinematic quantities, position, velocity, or acceleration, as a function of time, students will be able to determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.

1.2 Objective: Be able to describe the special case of motion with constant acceleration.

1.2.1 Performance Indicator: Students will be able to write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.

1.2.2 Performance Indicator: Students will be able to use the equations $\upsilon = \upsilon_0 + at$, $x = x_0 + \upsilon_0 t + ½ at^2$, and $\upsilon = \upsilon_0^2 + 2a(x - x_0)$ to solve problems involving one-dimensional motion with constant acceleration.

1.3 Objective: Be able to deal with situations in which acceleration is a specified function of velocity and time.

1.3.1 Performance Indicator: Students will be able to write an appropriate differential equation and solve it for $\upsilon(t)$ by separation of variables, incorporating correctly a given initial value of υ.

1.4 Objective: Be able to understand relationships and solve problems regarding motion in two dimensions, including projectile motion.

1.4.1 Performance Indicator: Students will be able to add, subtract, and resolve displacement and velocity vectors.

1.4.2 Performance Indicator: Students will be able to determine components of a vector along two specified, mutually perpendicular axes.

1.4.3 Performance Indicator: Students will be able to determine the net displacement of a particle or the location of a particle relative to another.

1.4.4 Performance Indicator: Students will be able to determine the change in velocity of a particle or the velocity of one particle relative to another.

1.5 Objective: Be able to describe the general motion of a particle in two dimensions .

1.5.1 Performance Indicator: Students will be able to solve problems regarding 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.

1.6 Objective: Be able to describe the motion of projectiles in a uniform gravitational field.

1.6.1 Performance Indicator: Students will be able to 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.

1.6.2 Performance Indicator: Students will be able to use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity.

Standard 2 - Students will be able to use Newton's laws of motion.

2.1 Objective: Be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several factors.

2.1.1 Performance Indicator: Students will be able to solve problems in which a particle remains at rest, or moves with constant velocity, under the influence of several factors.

2.2 Objective: Be able to determine the relation between the force that acts on an object and the resulting change in the object's velocity.

2.2.1 Performance Indicator: Students will be able to calculate, for an object moving in one dimension, the velocity change that results when a constant force *F* acts over a specified time interval.

2.2.2 Performance Indicator: Students will be able to calculate, for an object moving in one dimension, the velocity change that results when a force *F(t)* acts over a specified time interval.

2.2.3 Performance Indicator: Students will be able to 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.

2.3 Objective: Be able to determine how Newton's Second Law, $\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$, applies to an object subject to forces such as gravity, the pull of strings, or contact forces.

2.3.1 Performance Indicator: Students will be able to draw a well-labeled, free-body diagram showing all real forces that act on the object.

2.3.2 Performance Indicator: Students will be able to 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.

2.4 Objective: Be able to analyze situations in which an object moves with specified acceleration under the influence of one or more forces.

2.4.1 Performance Indicator: Students will be able to 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.

2.5 Objective: Be able to describe the significance of the coefficient of friction.

2.5.1 Performance Indicator: Students will be able to write down the relationship between the normal and frictional forces on a surface.

2.5.2 Performance Indicator: Students will be able to analyze situations in which an object moves along a rough inclined plane or horizontal surface.

2.5.3 Performance Indicator: Students will be able to analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction.

2.6 Objective: Be able to describe the effect of drag forces on the motion of an object.

2.6.1 Performance Indicator: Students will be able to find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity.

2.7 Objective: Be able to apply Newton's Third Law to calculations of systems of two or more objects.

2.7.1 Performance Indicator: Students will be able to use Newton's Third Law to identify the force pairs and the objects on which they act, and state the magnitude and direction of each force.

2.7.2 Performance Indicator: Students will be able to analyze 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.

2.7.3 Performance Indicator: Students will be able to explain 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.

2.7.4 Performance Indicator: Students will 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.

Standard 3 – Students will be able to understand work, energy, and power.

3.1 Objective: Be able to define work, including when it is positive, negative, or zero.

3.1.1 Performance Indicator: Students will be able to calculate the work done by a specified constant force on an object that undergoes a specified displacement.

3.1.2 Performance Indicator: Students will be able to 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 this case where the force is a linear function of position.

3.1.3 Performance Indicator: Students will be able to use the scalar product operation to calculate the work performed by a specified constant force *F* on an object that undergoes a displacement in a plane.

3.2 Objective: Be able to apply the work-energy theorem.

3.2.1 Performance Indicator: Students will be able to calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.

3.2.2 Performance Indicator: Students will be able to 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.

3.2.3 Performance Indicator: Students will be able to apply the theorem to determine the change in an object'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 an object to rest in a specified distance.

3.3 Objective: Be able to apply the concept of potential energy.

3.3.1 Performance Indicator: Students will be able to write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.

3.3.2 Performance Indicator: Students will be able to calculate the potential energy of one or more objects in a uniform gravitational field.

3.4 Objective: Be able to apply the concepts of mechanical energy and of total energy.

3.4.1 Performance Indicator: Students will be able to describe and identify situations in which mechanical energy is converted to other forms of energy.

3.4.2 Performance Indicator: Students will be able to analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force.

3.5 Objective: Be able to apply the law of conservation of energy.

3.5.1 Performance Indicator: Students will be able to identify situations in which mechanical energy is or is not conserved.

3.5.2 Performance Indicator: Students will be able to apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine.

3.5.3 Performance Indicator: Students will be able to apply conservation of energy in analyzing the motion of objects that move under the influence of springs.

3.6 Objective: Be able to apply the definition of power.

3.6.1 Performance Indicator: Students will be able to 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).

3.6.2 Performance Indicator: Students will be able to 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.

Standard 4 – Students will be able to understand systems of particles and linear momentum.

4.1 Objective: Be able to explain impulse and linear momentum.

4.1.1 Performance Indicator: Students will be able to relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects.

4.1.2 Performance Indicator: Students will be able to relate impulse to the change in linear momentum and the average force acting on an object.

4.1.3 Performance Indicator: Students will be able to calculate the area under a force versus time graph and relate it to the change in momentum of an object.

4.2 Objective: Be able to apply linear momentum conservation.

4.2.1 Performance Indicator: Students will be able to identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.

4.2.2 Performance Indicator: Students will be able to 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.

Standard 5 – Students will be able to solve problems regarding circular motion and rotation.

5.1 Objective: Be able to determine uniform circular motion of a particle.

5.1.1 Performance Indicator: Students will be able to relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

5.1.2 Performance Indicator: Students will be able to describe the direction of the particle's velocity and acceleration at any instant during the motion.

5.1.3 Performance Indicator: Students will be able to determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.

5.1.4 Performance Indicator: Students will 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, in situations such as the following: motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve); 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).

5.2 Objective: Be able to apply the concept of torque.

5.2.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the torque associate with a given force.

5.2.2 Performance Indicator: Students will be able to calculate the torque on a rigid object due to gravity.

5.3 Objective: Be able to analyze problems in statics.

5.3.1 Performance Indicator: Students will be able to state the conditions for translational and rotational equilibrium of a rigid object.

5.3.2 Performance Indicator: Students will be able to 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.

Standard 6 – Students will be able to understand oscillations and gravitation.

6.1 Objective: Be able to explain simple harmonic motion (dynamics and energy relationships).

6.1.1 Performance Indicator: Students will be able to 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.

6.1.2 Performance Indicator: Students will be able to write down an appropriate expression for displacement of the form $A \sin \omega t$ or $A \cos \omega t$ to describe the motion.

6.1.3 Performance Indicator: Students will be able to find an expression for velocity as a function of time.

6.1.4 Performance Indicator: Students will be able to 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.

6.1.5 Performance Indicator: Students will be able to state and apply the relation between frequency and period.

6.1.6 Performance Indicator: Students will be able to state how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic.

6.1.7 Performance Indicator: Students will be able to 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.

6.2 Objective: Be able to apply their knowledge of simple harmonic motion to the case of a mass on a spring.

6.2.1 Performance Indicator: Students will be able to apply the expression for the period of oscillation of a mass on a spring.

6.2.2 Performance Indicator: Students will be able to analyze problems in which a mass hangs from a spring and oscillates vertically.

6.2.3 Performance Indicator: Students will be able to analyze problems in which a mass attached to a spring oscillates horizontally.

6.3 Objective: Be able to apply their knowledge of simple harmonic motion to the case of a pendulum.

6.3.1 Performance Indicator: Students will be able to apply the expression for the period of simple pendulum.

6.3.2 Performance Indicator: Students will be able to state what approximation must be made in deriving the period.

6.4 Objective: Be able to use Newton's Law of Universal Gravitation.

6.4.1 Performance Indicator: Students will be able to determine the force that one spherically symmetrical mass exerts on another.

6.4.2 Performance Indicator: Students will be able to determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.

6.5 Objective: Be able to explain the motion of an object in orbit under the influence of gravitational forces.

6.5.1 Performance Indicator: Students will be able to recognize that, in a circular orbit, 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.

6.5.2 Performance Indicator: Students will be able to derive Kepler's Third Law for the case of circular orbits.

Fluid Mechanics and Thermal Physics
Standard 7 – Students will be able to solve problems involving fluid mechanics.

7.1 Objective: Be able to apply the concept of pressure as it applies to fluids.

7.1.1 Performance Indicator: Students will be able to apply the relationship between pressure, force, and area.

7.1.2 Performance Indicator: Students will be able to apply the principle that a fluid exerts pressure in all directions.

7.1.3 Performance Indicator: Students will be able to apply the principle that a fluid at rest exerts pressure perpendicular to any surface that it contacts.

7.1.4 Performance Indicator: Students will be able to determine locations of equal pressure in a fluid.

7.1.5 Performance Indicator: Students will be able to determine the values of absolute and gauge pressure for a particular situation.

7.1.6 Performance Indicator: Students will be able to apply the relationship between pressure and depth in a liquid, $\Delta P = \rho g \Delta h$.

7.2 Objective: Be able to explain the concept of buoyancy.

7.2.1 Performance Indicator: Students will be able to determine the forces on an object immersed partly or completely in a liquid.

7.2.2 Performance Indicator: Students will be able to apply Archimedes' principle to determine buoyant forces and densities of solids and liquids.

7.3 Objective: Be able to explain fluid flow continuity.

7.3.1 Performance Indicator: Students will be able to explain the equation of continuity so that they can apply it to fluids in motion.

7.4 Objective: Be able to use Bernoulli's equation.

7.4.1 Performance Indicator: Students will be able to explain Bernoulli's equation so that they can apply it to fluids in motion.

Standard 8 – Students will be able to solve problems involving temperature and heat.

8.1 Objective: Be able to solve problems involving the mechanical equivalent of heat.

8.1.1 Performance Indicator: Students will be able to apply the mechanical equivalent of heat: so they can determine how much heat can be produced by the performance of a specified quantity of mechanical work.

8.2 Objective: Be able to explain heat transfer and thermal expansion.

8.2.1 Performance Indicator: Students will be able to 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.

8.2.2 Performance Indicator: Students will be able to analyze what happens to the size and shape of an object when it is heated.

8.2.3 Performance Indicator: Students will be able to analyze qualitatively the effects of conduction, radiation, and convection in thermal processes.

Standard 9 – Students will be able to understand the kinetic theory and thermodynamics.

9.1 Objective: Be able to explain the kinetic theory model of an ideal gas.

9.1.1 Performance Indicator: Students will be able to state the assumptions of the model.

9.1.2 Performance Indicator: Students will be able to 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.

9.1.3 Performance Indicator: Students will be able to 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.

9.1.4 Performance Indicator: Students will be able to 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.

9.2 Objective: Be able to apply the ideal gas law and thermodynamic principles.

9.2.1 Performance Indicator: Students will be able to relate the pressure and volume of a gas during an isothermal expansion or compression.

9.2.2 Performance Indicator: Students will be able to 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.

9.2.3 Performance Indicator: Students will be able to calculate the work performed on or by a gas during an expansion or compression at constant pressure.

9.2.4 Performance Indicator: Students will be able to understand the process of adiabatic expansion or compression of a gas.

9.2.5 Performance Indicator: Students will be able to identify or sketch on a PV diagram the curves that represent each of the above processes.

9.3 Objective: Be able to apply the first law of thermodynamics.

9.3.1 Performance Indicator: Students will 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.

9.3.2 Performance Indicator: Students will be able to relate the work performed by a gas in a cyclic process to the area enclosed by a curve on a *PV* diagram.

9.4 Objective: Be able to comprehend the second law of thermodynamics, the concept of entropy, and heat engines and the Carnot cycle.

9.4.1 Performance Indicator: Students will be able to determine whether entropy will increase, decrease, or remain the same during a particular situation.

9.4.2 Performance Indicator: Students will be able to compute the maximum possible efficiency of a heat engine operating between two given temperatures.

9.4.3 Performance Indicator: Students will be able to compute the actual efficiency of a heat engine.

9.4.4 Performance Indicator: Students will be able to relate the heats exchanged at each thermal reservoir in a Carnot cycle to the temperatures of the reservoirs.

Electricity and Magnetism
Standard 10 – Students will be able to comprehend electrostatics.

10.1 Objective: Be able to grasp the concept of electric charge.

10.1.1 Performance Indicator: Students will be able to describe the types of charge and the attraction and repulsion of charges.

10.1.2 Performance Indicator: Students will be able to describe polarization and induced charges.

10.2 Objective: Be able to apply Coulomb's Law and the principle of superposition.

10.2.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the force on a positive or negative charge due to other specified point charges.

10.2.2 Performance Indicator: Students will be able to analyze the motion of a particle of specified charge and mass under the influence of an electrostatic force.

10.3 Objective: Be able to comprehend the concept of electric field.

10.3.1 Performance Indicator: Students will be able to define it in terms of the force on a test charge.

10.3.2 Performance Indicator: Students will be able to describe and calculate the electric field of a single point charge.

10.3.3 Performance Indicator: Students will be able to calculate the magnitude and direction of the electric field produced by two or more point charges.

10.3.4 Performance Indicator: Students will be able to calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field.

10.3.5 Performance Indicator: Students will be able to interpret an electric field diagram.

10.3.6 Performance Indicator: Students will be able to analyze the motion of a particle of specified charge and mass in a uniform electric field.

10.4 Objective: Be able to apply the concept of electric potential.

10.4.1 Performance Indicator: Students will be able to determine the electric potential in the vicinity of one or more point charges.

10.4.2 Performance Indicator: Students will be able to calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference.

10.4.3 Performance Indicator: Students will be able to determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials.

10.4.4 Performance Indicator: Students will be able to calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential.

10.4.5 Performance Indicator: Students will be able to calculate how much work is required to move a test charge form one location to another in the field of fixed point charges.

10.4.6 Performance Indicator: Students will be able to calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is require to establish the charge of a system.

Standard 11 – Students will be able to understand the concepts surrounding conductors and capacitors.

11.1 Objective: Be able to comprehend the nature of electric fields in and around conductors.

11.1.1 Performance Indicator: Students will be able to explain the mechanics responsible for the absence of electric field inside a conductor, and know that all excess charge must reside on the surface of the conductor.

11.1.2 Performance Indicator: Students will be able to explain why a conductor must be an equipotential, and apply this principle in analyzing what happens when conductors are connected by wires.

11.2 Objective: Be able to understand the nature of electric fields and electric potentials.

11.2.1 Performance Indicator: Students will be able to describe and sketch a graph of the electric field and potential inside and outside a charged conducting sphere.

11.3 Objective: Be able to understand induced charge and electrostatic shielding.

11.3.1 Performance Indicator: Students will be able to describe the process of charging by induction.

11.3.2 Performance Indicator: Students will be able to explain why a neutral conductor is attracted to a charged object.

11.4 Objective: Be able to understand the definition and function of capacitance.

11.4.1 Performance Indicator: Students will be able to relate stored charge and voltage for a capacitor.

11.4.2 Performance Indicator: Students will be able to relate voltage, charge, and stored energy for a capacitor.

11.4.3 Performance Indicator: Students will be able to recognize situations in which energy stored in a capacitor is converted to other forms.

11.5 Objective: Be able to understand the physics of the parallel-plate capacitor.

11.5.1 Performance Indicator: Students will be able to 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.

11.5.2 Performance Indicator: Students will be able to determine how changes in dimension will affect the value of the capacitance.

Standard 12 – Students should understand concepts surrounding electric circuits.

12.1 Objective: Be able to understand the definition of electric current.

12.1.1 Performance Indicator: Students will be able to relate the magnitude and direction of the current of flow of positive and negative charge.

12.2 Objective: Be able to understand conductivity, resistivity, and resistance.

12.2.1 Performance Indicator: Students will be able to relate the current voltage for a resistor.

12.2.2 Performance Indicator: Students will be able to describe how the resistance of a resistor depends upon its length and cross-sectional area, and apply this result in comparing current flow in resistors of different material or different geometry.

12.2.3 Performance Indicator: Students will be able to apply the relationships for the rate of heat production in a resistor.

12.3 Objective: Be able to understand the behavior of series and parallel combinations of resistors.

12.3.1 Performance Indicator: Students will be able to identify on a circuit diagram whether resistors are in series or in parallel.

12.3.2 Performance Indicator: Students will be able to determine the ratio of the voltage across resistors connected in series or the ratio of the currents through resistors connected in parallel.

12.3.3 Performance Indicator: Students will be able to calculate the equivalent resistance of a network of resistors that can be broken down into series and parallel combinations.

12.3.4 Performance Indicator: Students will be able to calculate the voltage, current, and power dissipation for any resistor in a network of resistors connected to a single power supply.

12.3.5 Performance Indicator: Students will be able design a simple series-parallel circuit that produces a given current through and potential difference across one specified component, and draw a diagram for the circuit using conventional symbols.

12.4 Objective: Be able to understand the properties of ideal and real batteries.

12.4.1 Performance Indicator: Students will be able to calculate the terminal voltage of a battery of specified emf and internal resistance from which a known current is flowing.

12.5 Objective: Be able to apply Ohm's law and Kirchhoff's rules to direct-current circuits.

12.5.1 Performance Indicator: Students will be able to determine a single unknown current, voltage, or resistance.

12.6 Objective: Be able to understand the properties of voltmeters and ammeters.

12.6.1 Performance Indicator: Students will be able to state whether the resistance of each is high or low.

12.6.2 Performance Indicator: Students will be able to identify or show correct methods of connecting meters into circuits in order to measure voltage or current.

12.7 Objective: Be able to understand the $t = 0$ and steady-state behavior of capacitors connected in series or in parallel.

12.7.1 Performance Indicator: Students will be able to calculate the equivalent capacitance of a series of parallel combination.

12.7.2 Performance Indicator: Students will be able to describe how stored charge is divided between capacitors connected in parallel.

12.7.3 Performance Indicator: Students will be able to determine the ratio of voltages for capacitors connected series.

12.7.4 Performance Indicator: Students will 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.

Standard 13 – Students will understand concepts regarding magnetic fields.

13.1 Objective: Be able to understand the force experienced by a charged particle in a magnetic field.

13.1.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the force in terms of q, **v**, and, **B**, and explain why the magnetic force can perform no work.

13.1.2 Performance Indicator: Students will be able to deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field.

13.1.3 Performance indicator: Students will be able to describe the paths of charged particles moving in uniform magnetic fields.

13.1.4 Performance Indicator: Students will be able to derive and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field.

13.1.5 Performance Indicator: Students will be able to describe under what conditions particles will move with constant velocity through crossed electric and magnetic fields.

13.2 Objective: Be able to understand the force exerted on a current-carrying wire in a magnetic field.

13.2.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field.

13.2.2 Performance Indicator: Students will be able to 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.

13.3 Objective: Be able to understand the magnetic field produced by a long straight current-carrying wire.

13.3.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the field at a point in the vicinity of such a wire.

13.3.2 Performance Indicator: Students will be able to use superposition to determine the magnetic field produced by two long wires.

13.3.3 Performance Indicators: Students will be able to calculate the force of attraction or repulsion between two long current-carrying wires.

Standard 14 – Students will understand concepts regarding electromagnetism.

14.1 Objective: Be able to understand the concept of magnetic flux.

14.1.1 Performance Indicator: Students will be able to calculate the flux of a uniform magnetic field through a loop of arbitrary orientation.

14.2 Objective: Be able to understand Faraday’s law and Lenz’s law.

14.2.1 Performance Indicator: Students will be able to calculate the magnitude and direction of the induced emf and current in a loop of wire or a conducting bar under the following condition: the magnitude of a related quantity such as a magnetic field or area of the loop is changing at a constant rate.

Waves and Sound
Standard 15 – Students will understand wave motion, including sound.

15.1 Objective: Be able to understand the description of traveling waves.

15.1.1 Performance Indicator: Students will be able to sketch or identify graphs that represent traveling waves and determine the amplitude, wavelength, and frequency of a wave form such a graph.

15.1.2 Performance Indicator: Students will be able to apply the relation among wavelength, frequency, and velocity.

15.1.3 Performance Indicator: Students will be able to understand qualitatively the Doppler Effect for sound in order to explain why there is a frequency shift in both the moving-source and moving-observer case.

15.1.4 Performance Indicator: Students will be able to describe reflection of a wave from the fixed or free end of a string.

15.1.5 Performance Indicator: Students will be able to describe qualitatively what factors determine the speed of waves on a string and the speed of sound.

15.2 Objective: Be able to understand the difference between transverse and longitudinal waves.

15.2.1 Performance Indicator: Students will be able to explain qualitatively why transverse waves can exhibit polarization.

15.3 Objective: Be able to understand the inverse-square law.

15.3.1 Performance Indicator: Students will be able to calculate the intensity of waves at a given distance form a source of specified power and compare the intensities at different distances from the source.

15.4 Objective: Be able to understand the physics of standing waves.

15.4.1 Performance Indicator: Students will be able to 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.

15.4.2 Performance Indicator: Students will be able to describe possible standing sound waves in a pipe that has either opened or closed ends, and determine the wavelength and frequency of such standing waves.

Standard 16 – Students will understand physical optics.

16.1 Objective: Be able to understand the principle of superposition.

16.1.1 Performance Indicator: Students will be able to apply the principle of superposition to traveling waves moving in opposite directions, and describe how a standing wave may be formed by superposition.

16.2 Objective: Be able to understand the interference and diffraction of waves.

16.2.1 Performance Indicator: Students will be able to apply the principles of interference to coherent sources in order to 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.

16.2.2 Performance Indicator: Students will be able to apply the principles of interference to 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.

16.2.3 Performance Indicator: Students will be able to apply the principles of interference to relate the amplitude produced by two or more sources that interfere constructively to the amplitude and intensity produced by a single source.

16.2.4 Performance Indicator: Students will be able to apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffracting grating to 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.

16.2.5 Performance Indicator: Students will be able to apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffracting grating to calculate, for a single-slit pattern, the angles or the positions on a distant screen where the intensity is zero.

16.2.6 Performance Indicator: Students will be able to apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffracting grating to 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.

16.2.7 Performance Indicator: Students will be able to apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffracting grating to calculate, for a two-slit interference pattern, the angles or the positions on a distant screen at which intensity maxima or minima occur.

16.2.8 Performance Indicator: Students will be able to apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffracting grating to describe or identify the interference pattern formed by a diffraction grating, 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.

16.2.9 Performance Indicator: Students will be able to apply the principles of interference to light reflected by thin films to state under what conditions a phase reversal occurs when light is reflected from the interface between two media of different indices of refraction.

16.2.10 Performance Indicator: Students will be able to apply the principles of interference to light reflected by thin films to determine whether rays of monochromatic light reflected perpendicularly 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.

16.3 Objective: Be able to understand dispersion and the electromagnetic spectrum.

16.3.1 Performance Indicator: Students will be able to relate a variation of index of refraction with frequency to a variation in refraction.

16.3.2 Performance Indicator: Students will be able to 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.

Standard 17 – Students will be able to understand the concepts surrounding geometric optics.

17.1 Objective: Be able to understand the principles of reflection and refraction.

17.1.1 Performance Indicator: Students will be able to determine how the speed and wavelength of light change when light passes from one medium into another.

17.1.2 Performance Indicator: Students will be able to show on a diagram the directions of reflected and refracted rays.

17.1.3 Performance Indicator: Students will be able to use Snell's Law to relate the directions of the incident ray and the refracted ray, and the indices of refraction of the media.

17.1.4 Performance Indicator: Students will be able to identify conditions under which total internal reflection will occur.

17.2 Objective: Be able to understand image formation by plane or spherical mirrors.

17.2.1 Performance Indicator: Students will be able to locate by ray tracing the image of an object formed by a plane mirror, and determine whether the image is real or virtual, upright or inverted, enlarged or reduced in size.

17.2.2 Performance Indicator: Students will be able to relate the focal point of a spherical mirror to its center of curvature.

17.2.3 Performance Indicator: Students will be able to locate by ray tracing the image of a real object, given a diagram of a mirror with the focal point shown, and determine whether the image is real or virtual, upright or inverted, enlarged or reduced in size.

17.2.4 Performance Indicator: Students will be able to use the mirror 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.

17.3 Objective: Understand image formation by converging or diverging lenses.

17.3.1 Performance Indicator: Students will be able to 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.

17.3.2 Performance Indicator: Students will be able to 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.

17.3.4 Performance Indicator: Students will be able to 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.

17.3.5 Performance Indicator: Students will be able to analyze simple situations in which the image formed by one lens serves as the object for another lens.

Atomic and Nuclear Physics
Standard 18 – Students will be able to understand atomic and quantum effects.

18.1 Objective: Be able to recognize the properties of photons.

18.1.1 Performance Indicator: Students will be able to relate the energy of a photon in joules or electron-volts to its wavelength or frequency.

18.1.2 Performance Indicator: Students will be able to 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.

18.1.3 Performance Indicator: Students will be able to calculate the number of photons per second emitted by a monochromatic source of specific wavelength and power.

18.2 Objective: Be able to understand the photoelectric effect.

18.2.1 Performance Indicator: Students will be able to describe a typical photoelectric-effect experiment, and explain what experimental observations provide evidence for the photon nature of light.

18.2.2 Performance Indicator: Students will be able to 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.

18.2.3 Performance Indicator: Students will be able to determine the maximum kinetic energy of photoelectrons ejected by photons of one energy or wavelength, when given the maximum kinetic energy of photoelectrons for a different photon energy or wavelength.

18.2.4 Performance Indicator: Students will be able to 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*.

18.3 Objective: Be able to understand Compton scattering.

18.3.1 Performance Indicator: Students will be able to describe Compton's experiment, and state what results were observed and by what sort of analysis these results may be explained.

18.3.2 Performance Indicator: Students will be able to account qualitatively for the increase of photon wavelength that is observed, and explain the significance of the Compton wavelength.

18.4 Objective: Be able to understand the nature and production of x-rays.

18.4.1 Performance Indicator: Students will be able to calculate the shortest wavelength of x-rays that may be produced by electrons accelerated through a specified voltage.

18.4 Objective: Be able to understand the concept of energy levels for atoms.

18.4.1 Performance Indicator: Students will be able to 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.

18.4.2 Performance Indicator: Students will be able to explain qualitatively the origin of emission or absorption spectra of gases.

18.4.3 Performance Indicator: Students will be able to calculate the wavelength or energy for a single-step transition between levels, given the wavelengths or energies of photons emitted or absorbed in a two-step transition between the same levels.

18.4.4 Performance Indicator: Students will be able to draw a diagram to depict the energy levels of an atom when given an expression for these levels, and explain how this diagram accounts for the various lines in the atomic spectrum.

18.5 Objective: Be able to understand the concept of de Broglie wavelength.

18.5.1 Performance Indicator: Students will be able to calculate the wavelength of a particle as a function of it momentum.

18.5.2 Performance Indicator: Students will be able to describe the Davisson-Germer experiment, and explain how it provides evidence for the wave nature of electrons.

Standard 19 – Students will understand concepts of nuclear physics.

19.1 Objective: Be able to understand the significance of the mass number and charge of nuclei.

19.1.1 Performance Indicator: Students will be able to interpret symbols for nuclei that indicate these quantities.

19.1.2 Performance Indicator: Students will be able to use conservation of mass number and charge to complete nuclear reactions.

19.1.3 Performance Indicator: Students will be able to determine the mass number and charge of a nucleus after it has undergone specified decay processes.

19.2 Objective: Be able to understand the nature of the nuclear force.

19.2.1 Performance Indicator: Students will be able to compare its strength and range with those of the electromagnetic force.

19.3 Objective: Be able to understand nuclear fission.

19.3.1 Performance Indicator: Students will be able to describe a typical neutron-induced fission and explain why a chain reaction is possible.

19.4 Objective: Be able to understand the relationship between mass and energy (mass-energy equivalence).

19.4.1 Performance Indicator: Students will be able to qualitatively relate the energy released in nuclear processes to the change in mass.

19.4.2 Performance Indicator: Students will be able to apply the relationship $\Delta E = (\Delta m)c^2$ in analyzing nuclear processes.

Laboratory and Experimental Situations

1. Design Experiments

Objective: Students will be able to understand the process of designing experiments.

> Performance Indicator: Students will be able to describe the purpose of an experiment or a problem to be investigated.
>
> Performance Indicator: Students will be able to identify equipment needed and describe how it is to be used.
>
> Performance Indicator: Students will be able to draw a diagram or provide a description of an experimental setup.
>
> Performance Indicator: Students will be able to describe procedures to be used, including controls and measurements to be taken.

2. Observation and measurement of real phenomena

Objectives: Students will be able to make relevant observations, and be able to make measurements with a variety of instruments (cannot be assessed via paper-and-pencil examinations).

> Performance Indicator: Students will be able to make relevant observations, and be able to make measurements with a variety of instruments (cannot be assessed via paper-and-pencil examinations).

3. Analyze data

Objective: Students will be able to understand how to analyze data.

> Performance Indicator: Students will be able to display data in graphical or tabular form.
>
> Performance Indicator: Students will be able to fit lines and curves to data points in graphs.
>
> Performance Indicator: Students will be able to perform calculations with data.
>
> Performance Indicator: Students will be able to make extrapolations and interpolations from data.

4. Analyze errors

Objective: Students will be able to understand measurement and experimental error.

Performance Indicator: Students will be able to identify sources of error and how they propagate.

Performance Indicator: Students will be able to estimate magnitude and direction of errors.

Performance Indicator: Students will be able to determine significant digits.

Performance Indicator: Students will be able to identify ways to reduce error.

5. Communicate results

Objective: Students will be able to understand how to summarize and communicate results.

Performance Indicator: Students will be able to draw inferences and conclusions from experimental data.

Performance Indicator: Students will be able to suggest ways to improve an experiment.

Performance Indicator: Students will be able to propose questions for further study.