LITCHFIELD PUBLIC SCHOOLS
Core Curriculum Scope and Sequence
AP Physics /12th grade

Name of Unit Weeks	CT Frameworks/ Standards	Content and Skill Objectives Students will be able to:	Assessments	Resources
Newtonian Mechanics (35%) **11 weeks**	Newton's laws predict the motion of most objects. When forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest. The law F = ma is used to solve motion problems that involve constant forces. When one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction. Applying a force to an object perpendicular to the direction of its motion causes the object to change direction.	**Kinematics** (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity, and acceleration) Motion in one dimension Students will 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. Students will understand the special case of motion with constant acceleration, so they can: (1) Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities. (2) Use the equations , $v = v_0 + at$, $x = x_0 + v_0t + ½ at^2$, and $v^2 = v_0^2 + 2a(x-x_0)$ and to solve problems involving one-dimensional motion with constant acceleration. **Motion in two dimensions**	RTP Lab 1 Introduction to Motion	

		Projectile Motion Students will be able to add, subtract, and resolve displacement and velocity vectors, so they can: (1) Determine components of a vector along two specified, mutually perpendicular axes. (2) Determine the net displacement of a particle or the location of a particle relative to another. (3) Determine the change in velocity of a particle or the velocity of one particle relative to another. Students will understand the motion of projectiles in a uniform gravitational field, so they can: (1)Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components. (2)Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity. **Newton's Laws of Motion** 1. Static equilibrium (first law) Students will be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces. 2. Dynamics of a single particle (second law) a) Students will understand the relation between the force that acts on an object and the resulting change in the object's velocity, so they can: (1) Calculate, for an object moving in one dimension, the velocity change that results when a constant force F acts over a specified time interval. (2) Calculate, for an object moving in one dimension, the velocity change that results when a force F(t) acts over a specified time interval. (3) Determine, for an object moving in a plane	RTP Lab 2 Changing Motion Inquiry Lab: Projectile Motion Mastering Physics: Introduction tutorial Puri Exp 3 Inclined Plane RTP Lab 3 Force and Motion Inquiry Lab: Force Table	

		whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the object. b) Students will understand how Newton's Second Law, , applies to an object subject to forces such as gravity, the pull of strings, or contact forces, so they can: (1) Draw a well-labeled, free-body diagram showing all real forces that act on the object. (2) Write down the vector equation that results from applying Newton's Second Law to the object, and take components of this equation along appropriate axes. c) Students 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, such as motion up or down with constant acceleration. d) Students will understand the significance of the coefficient of friction, so they can: (1) Write down the relationship between the normal and frictional forces on a surface. (2) Analyze situations in which an object moves along a rough inclined plane or horizontal surface. (3) Analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction. e) Students will understand the effect of drag forces on the motion of an object, so they can: Find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity. 3. Systems of two or more objects (third law) a) Students will understand Newton's Third Law so that, for a given system, they can identify the force pairs and the objects on which	Puri Exp 4 Composition and Resolution of Forces Mastering Physics: Linear Momentum tutorial Mastering Physics: Linear Momentum problems Puri Exp 11 Centripetal Force Mastering Physics: Rotational Momentum tutorial Mastering Physics: Rotational Momentum problems Mastering Physics:VIbratin and Waves tutorial Puri Exp 12 Vibratory Motion of a Spring PwC Exp 10 Atwood's Machine Inquiry Lab: Momentum and Collisions Puri Exp 9 Elastic Collisions PwC Lab: Pendulum Periods	

		they act, and state the magnitude and direction of each force. b) Students will be able to apply Newton's Third Law in analyzing the force of contact between two objects that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another. c) Students will know that the tension is constant in a light string that passes over a massless pulley and will be able to use this fact in analyzing the motion of a system of two objects joined by a string. d) 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. **Work, energy and power** Objectives: 1. Work and the work-energy theorem a) Students will understand the definition of work, including when it is positive, negative, or zero, so they can: (1) Calculate the work done by a specified constant force on an object that undergoes a specified displacement. (2) Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position. (3) Use 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. b) Students will understand and be able to apply the work-energy theorem, so they can: (1) Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object. (2) Calculate the work performed by the net		

	The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. Kinetic energy can be calculated by using the formula $E = (1/2)mv^2$. Changes in gravitational potential energy near Earth can be calculated by using the formula (change in potential energy) = mgh. Momentum is calculated as the product mv. Momentum is a separately conserved quantity different from energy. An unbalanced force on an object produces a change in its momentum. The principles of conservation of momentum and energy can be used to solve problems	force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy. (3) Apply the theorem to determine the change in an object's kinetic energy and speed that 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. 2. Forces and potential energy (1) Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring. (2) Calculate the potential energy of one or more objects in a uniform gravitational field. 3. Conservation of energy a) Students will understand the concepts of mechanical energy and of total energy, so they can: (1) Describe and identify situations in which mechanical energy is converted to other forms of energy. (2) Analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force. b) Students will understand conservation of energy, so they can: (1) Identify situations in which mechanical energy is or is not conserved. (2) Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine. (3) Apply conservation of energy in analyzing the motion of objects that move under the influence of springs. (4) Apply conservation of energy in analyzing the motion of objects that move under the influence of other non-constant one-dimensional forces.		

	involving elastic and inelastic collisions.	c) Students will be able to recognize and solve problems that call for application both of conservation of energy and Newton's Laws. 4. Power Students will understand the definition of power, so they can: a) Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed). b) Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work. **Linear Momentum** Systems of particles, linear momentum 1. Impulse and momentum Students will understand impulse and linear momentum, so they can: a) Relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects. b) Relate impulse to the change in linear momentum and the average force acting on an object. c) Calculate the area under a force versus time graph and relate it to the change in momentum of an object. 2. Conservation of linear momentum, collisions a) Students will understand linear momentum conservation, so they can: (1) Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved. (2) Apply linear momentum conservation to one-dimensional elastic and inelastic collisions		

		and two-dimensional completely inelastic collisions. (3) 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. Uniform Circular Motion and Gravitation 1. **Uniform circular motion** Students will understand the uniform circular motion of a particle, so they can: a) Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration. b) Describe the direction of the particle's velocity and acceleration at any instant during the motion. c) Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities. d) Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following: (1) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve (2) Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel). 2. **Newton's law of gravity** Students will know Newton's Law of Universal Gravitation, so they can: a) Determine the force that one spherically symmetrical mass exerts on another. b) Determine the strength of the gravitational field at a specified point outside a spherically		

	Circular motion requires the application of a constant force directed toward the center of the circle. Waves have characteristic properties that do not depend on the type of wave. Waves carry energy from one	symmetrical mass. 3. Orbits of planets and satellites Students will understand the motion of an object in orbit under the influence of gravitational forces, so they can: a) For a circular orbit: (1) Recognize that the motion does not depend on the object's mass; describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit. (2) Derive Kepler's Third Law for the case of circular orbits. **Torque and Rotational Statics Angular momentum and conservation** 2. Torque and rotational statics a) Students will understand the concept of torque, so they can: (1) Calculate the magnitude and direction of the torque associated with a given force. (2) Calculate the torque on a rigid object due to gravity. b) Students will be able to analyze problems in statics, so they can: (1) State the conditions for translational and rotational equilibrium of a rigid object. (2) Apply these conditions in analyzing the equilibrium of a rigid object under the combined influence of a number of coplanar forces applied at different locations. **Vibrations and Waves** 1. Simple harmonic motion (dynamics and energy relationships) Students will understand simple harmonic motion, so they can: a) Sketch or identify a graph of displacement as		

	place to another. Transverse and longitudinal waves exist in mechanical media, such as springs and ropes, and in the Earth as seismic waves. Wavelength, frequency and wave speed are related. Sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates. Radio waves, light and X-rays are different wavelength bands in the spectrum of electromagnetic waves, the speed of which in a vacuum is approximately 3 x 10^8m/s, and less when passing through other media. Waves have characteristic behaviors, such as interference, diffraction, refraction and polarization. Beats and the Doppler Effect result from the characteristic behavior of waves.	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 Asinwt or Acoswt to describe the motion. c) 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. d) State and apply the relation between frequency and period. e) 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. f) 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. 2. Mass on a spring Students will be able to apply their knowledge of simple harmonic motion to the case of a mass on a spring, so they can: a) Derive the expression for the period of oscillation of a mass on a spring. b) Apply the expression for the period of oscillation of a mass on a spring. c) Analyze problems in which a mass hangs from a spring and oscillates vertically. d) Analyze problems in which a mass attached to a spring oscillates horizontally. 3. Pendulum and other oscillations Students will be able to apply their knowledge of simple harmonic motion to the case of a		

		pendulum, so they can: a) Derive the expression for the period of a simple pendulum. b) Apply the expression for the period of a simple pendulum. c) State what approximation must be made in deriving the period.		

Name of Unit Weeks	**CT Frameworks/ Standards**	**Content and Skill Objectives** Students will be able to:	**Assessments**	**Resources**
Fluid Mechanics, Heat, Kinetic Theory, and Thermodynamics (15%) **4 Weeks**	Energy cannot be created or destroyed although, in many processes, energy is transferred to the environment as heat. Heat flow and work are two forms of energy transfer between systems. The work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature. The internal energy of an object includes the energy of random motion of the object's atoms and molecules. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object. Most processes tend to decrease the order of a system over time, so that energy levels eventually are distributed more uniformly.	**Fluid Mechanics** **1. Hydrostatic pressure** Students will understand the concept of pressure as it applies to fluids, so they can: a) Apply the relationship between pressure, force, and area. b) Apply the principle that a fluid exerts pressure in all directions. c) Apply the principle that a fluid at rest exerts pressure perpendicular to any surface that it contacts. d) Determine locations of equal pressure in a fluid. e) Determine the values of absolute and gauge pressure for a particular situation. f) Apply the relationship between pressure and depth in a liquid, $\Delta P = \rho g \Delta h$. **2. Buoyancy** Students will understand the concept of buoyancy, so they can: a) Determine the forces on an object immersed partly or completely in a liquid. b) Apply Archimedes' principle to determine buoyant forces and densities of solids and liquids. **3. Fluid flow continuity** Students will understand the equation of continuity so that they can apply it to fluids in motion **4. Bernoulli's equation**	Puri Exp 14 Boyle's Law	

		Students will understand Bernoulli's equation so that they can apply it to fluids in motion. Objectives: Temperature and heat 1. Mechanical equivalent of heat Students will understand 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. 2. Heat transfer and thermal expansion Students will understand heat transfer and thermal expansion, so they can: a) 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. b) Analyze what happens to the size and shape of an object when it is heated. c) Analyze qualitatively the effects of conduction, radiation, and convection in thermal processes. Kinetic theory and thermodynamics 1. Ideal gases a) Students will 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. (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 will 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. 2. Laws of thermodynamics a) Students will 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 will 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.		

		(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.		

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Electricity and Magnetism (25%) **5 weeks**	Electric and magnetic phenomena are related and have many practical applications. The voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors and capacitors can be predicted using Ohm's law. Any resistive element in a DC circuit dissipates energy, which heats the resistor. The power in any resistive circuit element can be calculated by using the formula Power = I^2R. Charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges. Magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources.	Electrostatics 1. Charge and Coulomb's Law a) Students will understand the concept of electric charge, so they can: (1) Describe the types of charge and the attraction and repulsion of charges. (2) Describe polarization and induced charges. b) Students will understand Coulomb's Law and the principle of superposition, so they can: (1) Calculate the magnitude and direction of the force on a positive or negative charge due to other specified point charges. (2) Analyze the motion of a particle of specified charge and mass under the influence of an electrostatic force. 2. Electric field and electric potential (including point charges) a) Students will understand the concept of electric field, so they can: (1) Define it in terms of the force on a test charge. (2) Describe and calculate the electric field of a single point charge. (3) Calculate the magnitude and direction of the electric field produced by two or more point charges. (4) Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field. (5) Interpret an electric field diagram. (6) Analyze the motion of a particle of specified charge and mass in a uniform electric field.	RTP Lab 1 Batteries, bulbs and current RTP Lab 2 DC Circuits RTP Lab 3 Voltage and Ohm's Law RTP Lab 4 Kirchkoff's Rules RTP Lab 5 Intro to RC Circuits Puri Experiment 25: Resistance in Series and Parallel Circuits PwC Exp 28 The Magnetic Field in a Coil PwC Exp 29 The Magnetic Field in a Slinky	

	Changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors. Plasmas, the fourth state of matter, contain ions, or free electrons or both and conduct electricity.	b) Students will understand the concept of electric potential, so they can: (1) Determine the electric potential in the vicinity of one or more point charges. (2) 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. (3) Determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials. (4) Calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential. (5) Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges. (6) Calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to establish the charge system. Conductors, capacitors, dielectrics 1. Electrostatics with conductors a) Students will 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 know that 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) Show 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. b) Students will be able to describe and sketch a graph of the electric field and potential inside		

		and outside a charged conducting sphere. c) Students will understand induced charge and electrostatic shielding, so they can: (1) Describe the process of charging by induction. (2) Explain why a neutral conductor is attracted to a charged object. 2. Capacitors a) Students will understand the definition and function of capacitance, so they can: (1) Relate stored charge and voltage for a capacitor. (2) Relate voltage, charge, and stored energy for a capacitor. (3) Recognize situations in which energy stored in a capacitor is converted to other forms. b) Students will 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. Electric circuits 1. Current, resistance, power a) Students will understand the definition of electric current, so they can relate the magnitude and direction of the current to the rate of flow of positive and negative charge b) Students will understand conductivity, resistivity, and resistance, so they can: (1) Relate current and voltage for a resistor. (2) 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. (3) Apply the relationships for the rate of heat production in a resistor. 2. Steady-state direct current circuits with batteries and resistors only a) Students will 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. (3) Calculate the equivalent resistance 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 power supply. (5) 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. b) Students will 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. c) Students will 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. d) Students will 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. Magnetic Fields 1. Forces on moving charges in magnetic fields Students will understand the force experienced by a charged particle in a magnetic field, so they can: a) 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. b) Deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field. c) Describe the paths of charged particles moving in uniform magnetic fields. d) Derive and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field. e) Describe under what conditions particles will move with constant velocity through crossed electric and magnetic fields. 2. Forces on current-carrying wires in magnetic fields Students will understand the force exerted on a current-carrying wire in a magnetic field, so they can: a) Calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field. b) 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. c) Calculate the magnitude and direction of the torque experienced by a rectangular loop of wire carrying a current in a magnetic field. 3. Fields of long current-carrying wires		

		Students will understand the magnetic field produced by a long straight current-carrying wire, so they can: a) Calculate the magnitude and direction of the field at a point in the vicinity of such a wire. b) Use superposition to determine the magnetic field produced by two long wires. c) Calculate the force of attraction or repulsion between two long current-carrying wires. Electromagnetism 1. Electromagnetic induction (including Faraday's law and Lenz's law) a) Students will understand the concept of magnetic flux, so they can: (1) Calculate the flux of a uniform magnetic field through a loop of arbitrary orientation. b) Students will 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. (2) Calculate the magnitude and direction of the induced emf and current in a loop of wire or a conducting bar under the following conditions: (a) The magnitude of a related quantity such as magnetic field or area of the loop is changing at a constant rate		

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Waves and Optics (15%) **5 Weeks**		**Dispersion of light and the electromagnetic spectrum** Students will understand dispersion and the electromagnetic spectrum, so they can: 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. Wave motion (including sound) 1. Traveling waves Students will understand the description of traveling waves, 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) Apply the relation among wavelength, frequency, and velocity for a wave. c) 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. d) Describe reflection of a wave from the fixed or free end of a string. e) Describe qualitatively what factors determine the speed of waves on a string and the speed of sound. 2. Wave propagation	PwC Lab: Sound Waves and Beats Lab: Diffraction Grating Lab: LED Lab: Reflection Lab: Index of Refraction	

		a) Students will understand the difference between transverse and longitudinal waves, and be able to explain qualitatively why transverse waves can exhibit polarization. b) Students will understand the inverse-square law, so they can calculate the intensity of waves at a given distance from a source of specified power and compare the intensities at different distances from the source. 3. Standing waves Students will understand the physics of standing waves, 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. 4. Superposition Students will understand the principle of superposition, so they can apply it to traveling waves moving in opposite directions, and describe how a standing wave may be formed by superposition. **Physical optics** 1. Interference and diffraction Students will understand the interference and diffraction of waves, so they can: a) Apply the principles of interference to coherent sources 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 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 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. 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 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. Dispersion of light and the electromagnetic spectrum Students will understand dispersion and the electromagnetic spectrum, so they can: a) Relate a variation of index of refraction with frequency to a variation in refraction. **Geometric optics** 1. Reflection and refraction Students will understand the principles of reflection and refraction, 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. 2. Mirrors Students will understand image formation by plane or spherical mirrors, so they can: a) 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. b) Relate the focal point of a spherical mirror to its center of curvature. c) 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. d) 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. 3. Lenses Students will understand image formation by converging or diverging lenses, 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.		

Name of Unit Weeks	**CT Frameworks/ Standards**	**Content and Skill Objectives** Students will be able to:	**Assessments**	**Resources**
Modern Physics (10%) **5 weeks**		**ATOMIC AND NUCLEAR PHYSICS** **Atomic physics and quantum effects** 1. Photons, the photoelectric effect, Compton scattering, x-rays a) Students will know the properties of photons, so they can: (1) Relate the energy of a photon in joules or electron-volts to its wavelength or frequency. (2) 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. (3) Calculate the number of photons per second emitted by a monochromatic source of specific wavelength and power. b) Students will understand the photoelectric effect, so they can: (1) Describe a typical photoelectric-effect experiment, and explain what experimental observations provide evidence for the photon nature of light. (2) 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. (3) 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. (4) 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. c) Students will understand Compton scattering, so they can: (1) Describe Compton's experiment, and state what results were observed and by what sort of analysis these results may be explained. (2) Account qualitatively for the increase of photon wavelength that is observed, and explain the significance of the Compton wavelength. d) Students will understand the nature and production of x-rays, so they can calculate the shortest wavelength of x-rays that may be produced by electrons accelerated through a specified voltage. 2. Atomic energy levels Students will understand the concept of energy levels for atoms, so they can: 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) 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. d) 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.		

		3. Wave-particle duality Students will understand the concept of de Broglie wavelength, 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. **Nuclear Physics** 1. Nuclear reactions (including conservation of mass number and charge) a) Students will understand the significance of the mass number and charge of nuclei, so they can: (1) Interpret symbols for nuclei that indicate these quantities. (2) Use conservation of mass number and charge to complete nuclear reactions. (3) Determine the mass number and charge of a nucleus after it has undergone specified decay processes. b) Students will know the nature of the nuclear force, so they can compare its strength and range with those of the electromagnetic force. c) Students will understand nuclear fission, so they can describe a typical neutron-induced fission and explain why a chain reaction is possible. 2. Mass-energy equivalence Students will understand the relationship between mass and energy (mass-energy equivalence), so they can: a) Qualitatively relate the energy released in nuclear processes to the change in mass. b) Apply the relationship $\Delta E=\Delta mc2$ in analyzing nuclear processes. Students will understand the relationship between a researched particle to other particles in the standard model.		

		a) Describe the significance of a researched particle to the development of the standard model. b) Describe equations of reactions between particles. **Status of the Standard Model** Students will investigate the latest research in particle physics at CERN and other particle research websites (Fermilab, Stanford, etc.) so they can: a) Relate their particle research to current research. b) Compare predictions of direction of particle physics research to current information. **String Theory** Students will understand the basis of string theory as an alternate model of the structure of matter. Students will compare and contrast the string theory model to previously studied models of matter. **Astrophysics and Cosmology** Students will view the work of Stephen Hawkings in the context of the study of cosmology and the universe. Students will compare and contrast models of expansion and contraction of the universe.	Virtual lab: Photoelectric effect Lab: Half-life of pennies Research project: Standard Model CERN website investigation The Elegant Universe video and related items from Brian Greene, PBS website Stephen Hawkings Universe video and PBS website	