| Content Area: Science | Course: AP Physics 2 | Grade Level: 12 |
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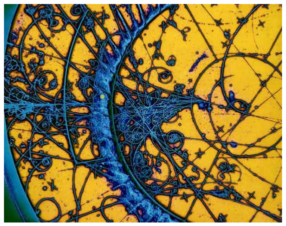
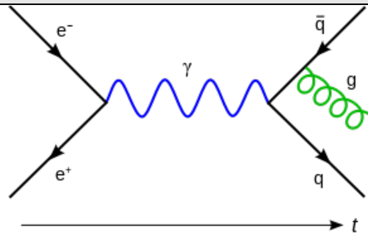
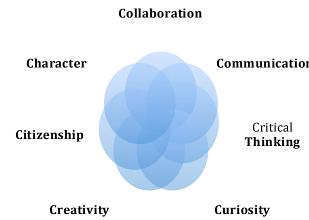
|   | R14 The Seven Cs of Learning  | |





| Unit Titles | Length of Unit |
|---|---|
| • Fluids | • 4-5 weeks |
| • Thermodynamics | • 4-5 weeks |
| • Electricity | • 4-5 weeks |
| • Circuits | • 3-4 weeks |
| • Electromagnetism | • 5-6 weeks |
| • Waves and Optics | • 4-5 weeks |
| • Modern Physics | • 5-6 weeks |

| Strands | Course Level Expectations |
|---|---|
| **Big Idea 1** | • Objects and systems have properties such as mass and charge.<br>• Systems may have internal structure. |
| **Big Idea 2** | • Fields existing in space can be used to explain interactions. |
| **Big Idea 3** | • The interactions of an object with other objects can be described by forces. |
| **Big Idea 4** | • Interactions between systems can result in changes in those systems. |
| **Big Idea 5** | • Changes that occur as a result of interactions are constrained by conservation laws. |
| **Big Idea 6** | • Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena. |
| **Big Idea 7** | • The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems. |

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| **Unit Title** | Fluids | **Length of Unit** | 4-5 weeks |

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| **Inquiry Questions** **(Engaging & Debatable)** | • How does the height of a building affect the design of the plumbing<br>• Why is a wounded limb elevated?<br>• How do planes fly? |
| **Standards*** | **Big Ideas:** 1, 3, 5<br>**Learning Objectives:** 1.E.1; 3.A.2; 3.A.3; 3.A.4; 3.B.1; 3.B.2; 3.C.4; 5.B.10; 5.F.1 |
| **Unit Strands & Concepts** | • Measures and Applies Density to floating and submerged problems and lab situations;<br>• Applies Pressure concept correctly in Hydrostatics and Hydrodynamics problems and lab situations. |
| **Key Vocabulary** | Density, Pressure, Fluid, Volume Flow Rate, Hydrostatic, Hydrodynamic |

*Standards based on AP Physics 2: Algebra-Based Course and Exam Description
For more information visit: http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html

| **Unit Title** | Fluids | **Length of Unit** | 4-5 weeks |
|---|---|---|---|

| **Critical Content:**<br>**My students will Know...** | **Key Skills:**<br>**My students will be able to (Do)...** |
|---|---|
| • how to determine density using Archimedes Principle<br>• how to describe the motion of a submerged object using Newton's 2nd Law and buoyant force<br>• describe the energy state of a fluid using Bernoulli's Equations<br>• describe how the conservation of mass results in the continuity equation<br>• buoyant forces result from the interaction of one object touching another object and they arise from interatomic electric forces. | • construct representations of how the properties of a system are determined by the interactions of its constituent substructures.<br>• draw free body diagrams for floating and submerged objects<br>• find how fast a fluid is moving or what pressure it has based on the continuity o fluids and Bernoulli's Equation.<br>• predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.<br>• explain buoyant forces as arising from interatomic electric forces and that they therefore have certain directions. |

| **Assessments:** | • Lab Reports, Formative Assessments, Fluids Unit Assessment |
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| **Teacher Resources:** | Unit implementation Guide<br>*Physics* Walker 3rd edition, AP Physics 1 and 2 Inquiry-Based Lab Investigations, Lab equipment, Department Lab Report rubric, Phet simulations (available online) |

| **Unit Title** | Thermodynamics | **Length of Unit** | 4-5 weeks |
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| **Inquiry Questions (Engaging & Debatable)** | • How is a gas able to do work?<br>• Why can't all the energy available be used?<br>• How do internal combustion engines and heat pumps work? |
| **Standards*** | **Big Ideas:** 1, 5, 7<br>**Learning Objective:** 1.A.5; 1.E.3; 4.C.3; 5.B.2; 5.B.4; 5.B.5; 5.B.6; 5.B.7; 5.D.1; 5.D.2; 7.A.1; 7.A.2; 7.A.3; 7.B.1; 7.B.2 |
| **Unit Strands & Concepts** | • Apply the laws of Thermodynamics and Conservation of Energy to systems involving gases experiencing changes in temperature, volume and pressure, while doing work or having work done on them.<br>• Relate these systems to the operation of internal combustion engines, turbines and other heat engines.<br>• Understand the reasons why all energy can not be used and entropy increases. |
| **Key Vocabulary** | Heat, Temperature, isovolumetric, isothermal, isobaric, adiabatic, entropy |

| Unit Title | Thermodynamics | Length of Unit | 4-5 weeks |
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| Critical Content: My students will Know… | Key Skills: My students will be able to (Do)… |
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| • matter has a property called thermal conductivity. Thermal conductivity is the measure of a material's ability to transfer thermal energy.<br>• energy is transferred spontaneously from a higher temperature system to a lower temperature system. The process through which energy is transferred between systems at different temperatures is called heat.<br>• energy can be transferred by thermal processes involving differences in temperature; this process of transfer is called heat.<br>• the first law of thermodynamics is a specific case of the law of conservation of energy involving the internal energy of a system and the possible transfer of energy through work and/or heat. Examples include P-V diagrams — isovolumetric process, isothermal process, isobaric process, and adiabatic process. No calculations of thermal energy or internal energy from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.<br>• the pressure of a system determines the force that the | • design an experiment and analyze data from it to examine thermal conductivity.<br>• make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level.<br>• describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.<br>• predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.<br>• create a plot of pressure versus volume for a thermodynamic process from given data.<br>• use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the rst law of thermodynamics).<br>• analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables |

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| system exerts on the walls of its container and is a measure of the average change in the momentum or impulse of the molecules colliding with the walls of the container. The pressure also exists inside the system itself, not just at the walls of the container.<br>• the temperature of a system characterizes the average kinetic energy of its molecules.<br>• in an ideal gas, the macroscopic (average) pressure ($P$), temperature ($T$), and volume ( ), are related by the ideal gas law<br>• the second law of thermodynamics describes the change in entropy for reversible and irreversible processes. | • connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.<br>• design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.<br>• analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV \quad nRT$.<br>• connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes. |

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| **Assessments:** | • Lab Reports, Problem Sets<br>• Thermodynamics Formative Assessment |
| **Teacher Resources:** | Unit implementation Guide, *Physics* Walker 3rd edition<br>AP Physics 1 and 2 Inquiry-Based Lab Investigations<br>Lab equipment (including pressure sensors flasks and Bunsen burners)<br>Department Lab Report rubric, Phet simulations (available online) |

| **Unit Title** | Electricity | **Length of Unit** | 4-5 weeks |
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| **Inquiry Questions (Engaging & Debatable)** | • Why and how can a balloon be attached to a wall?<br>• Is moving a charge through a conductor without doing work a violation of the law of conservation of energy?<br>• The electric forces from charges can cancel; do the electric potential energies neutralize each other? |
| **Standards*** | **Big Idea:** 1, 2, 3, 5<br>**Learning Objectives:** 1.B.1; 1.B.2; 1.B.3; 2.C.1; 2.C.2; 2.C.3; 2.C.4; 2.C.5; 2.E.2; 2.E.3; 3.C.2; 3.G.2; 4.E.3; 5.B.2; 5.C.2 |
| **Unit Strands & Concepts** | • Evaluates static charged systems to determine distribution of charge, electric field and potential field.<br>• Applying Coulomb's Law and definition of Electric Field to problems involving force, charge, mass and tension.<br>• Appling knowledge of parallel plate capacitors to motion of particles, storage of energy and strength of field problems. |
| **Key Vocabulary** | Charge, Permeability, Current, Vector Field, Scalar Field, Electric Field, Capacitance, Electric Potential, Isoline |

| Unit Title | Electricity | Length of Unit | 4-5 weeks |
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| Critical Content: My students will Know... | Key Skills: My students will be able to (Do)... |
|---|---|
| • electric charge is conserved.<br>• there are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.<br>• the smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.<br>• the magnitude of the electric force exerted on an object with electric charge by an electric field E is $F=qE$ The direction of the force is determined by the direction of the field and the sign of the charge.<br>• the magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field.<br>• the electric field outside a spherically symmetric charged object is radial and its magnitude varies as the inverse square of the radial distance from the center of that object.<br>• the electric field around dipoles and other systems of electrically charged objects (that can be modeled as point objects) is found by vector addition of the field of each individual object. | • make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes.<br>• make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.<br>• predict the direction and the magnitude of the force exerted on an object with an electric charge $q$ placed in an electric field using the mathematical model of the relation between an electric force and an electric field.<br>• calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.<br>• qualitatively and semi quantitatively apply the vector relationship between the electric field and the net electric charge creating that field.<br>• explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object.<br>• distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field).<br>• calculate the magnitude and determine the direction of the electric |

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| • Between two oppositely charged parallel plates with uniformly distributed electric charge, at points far from the edges of the plates, the electric field is perpendicular to the plates and is constant in both magnitude and direction.<br>• Isolines in a region where an electric field exists represent lines of equal electric potential, referred to as equipotential lines.<br>• The average value of the electric field in a region equals the change in electric potential across that region divided by the change in position (displacement) in the relevant direction.<br>• Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.<br>• Electromagnetic forces are exerted at all scales and can dominate at the human scale.<br>• The charge distribution in a system can be altered by the ects of electric forces produced by a charged object.<br>• The exchange of electric charges among a set of objects in system conserves electric charge. | field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.<br>• represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in the Earth's gravitational field.<br>• qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects.<br>• apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated.<br>• use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges.<br>• make predictions about the redistribution of charge during charging by friction, conduction, and induction.<br>• design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data. |

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| **Assessments:** | • Lab Reports, Formative Assessments, Problem Sets<br>• Electrostatics Tests |
| **Teacher Resources:** | Unit Implementation Guide, *Physics* Walker 3rd edition, AP Physics 1 and 2 Inquiry-Based Lab Investigations<br>Lab equipment including meters, power supplies, circuit elements, Department Lab Report rubric, Phet simulations |

| Unit Title | Circuits | Length of Unit | 3-4 weeks |
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| **Inquiry Questions (Engaging & Debatable)** | • Why does everything plugged into your house get the current it wants?<br>• How does a battery charger work? |
| **Standards*** | **Big Idea:** 4 and 5<br>**Learning Objectives:** 1.E.2; 4.E.4; 4.E.5; 5.B.9; 5.C.3 |
| **Unit Strands & Concepts** | • Find and explain resistivity;<br>• Calculate voltage, current, resistance and capacitance for a variety of circuits;<br>• Apply Kirchoff's Laws to predict the behavior of more complex circuits. |
| **Key Vocabulary** | Resistivity, Resistance, Current, Voltage, Potential Difference, Electromotive Force, Electric Power, Capacitance |

| Unit Title | Circuits | Length of Unit | 3-4 weeks |
|---|---|---|---|

| Critical Content: My students will Know… | Key Skills: My students will be able to (Do)… |
|---|---|
| ● matter has a property called resistivity.<br>● the resistance of a resistor, and the capacitance of a capacitor, can be understood from the basic properties of electric fields and forces, as well as the properties of materials and their geometry.<br>● the values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.<br>● Kirchhoff's loop rule describes conservation of energy in electrical circuits.<br>● Kirchhoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. | ● choose and justify the selection of data needed to determine resistivity for a given material.<br>● design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.<br>● make and justify a quantitative prediction of the e ect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.<br>● mathematically express the changes in electric potential energy of a loop in a multi loop electrical circuit and justify this expression using the principle of the conservation of energy.<br>● determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit. |

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| **Assessments:** | • Lab Reports, Quizzes, Problem Sets and Circuits Tests |
| **Teacher Resources:** | Unit implementation Guide, *Physics* Walker 3rd edition AP Physics 1 and 2 Inquiry-Based Lab Investigations, Lab equipment including meters, power supplies, Circuit elements, Department Lab Report rubric, Phet simulations |

| Unit Title | Electromagnetism | Length of Unit | 5-6 weeks |
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| **Inquiry Questions (Engaging & Debatable)** | • Why does a magnet fall more slowly through a copper pipe than through a plastic pipe?<br>• How does an electric motor exert torque if the coils never touch the magnets?<br>• How does a transformer convert power from the house current to your phone's current? |
| **Standards*** | **Big Idea:** 1, 2, 4<br>**Learning Objectives:** 1.E.5; 2.D.1; 2.D.2; 2.D.3; 2.D.4; 3.C.3; 4.E.1; 4.E.2 |
| **Unit Strands & Concepts** | • Measure and describe magnetic fields created by magnets, electromagnets and inside loops of wire.<br>• Calculate the behavior of currents and charged particles in magnetic fields. Apply Faraday's and<br>• Lenz's Laws to explain and calculate the effects of changing magnetic fields on coils of wire |
| **Key Vocabulary** | Magnetic permeability, cross product, right hand rule, magnetic domain, permanent magnetism, soft magnetism, solenoid, induction, emf, Lenz's Law, Faraday's Law |

| Unit Title | Electromagnetism | Length of Unit | 5-6 weeks |
|---|---|---|---|

| **Critical Content:**<br>**My students will Know...** | **Key Skills:**<br>**My students will be able to (Do)...** |
|---|---|
| • matter has a property called magnetic permeability.<br>• the magnetic field exerts a force on a moving electrically charged object.<br>• the magnetic field vectors around a straight wire that carries electric current are tangent to concentric circles centered on that wire.<br>• Ferromagnetic materials contain magnetic domains that are themselves magnets.<br>• a magnetic force results from the interaction of moving charged object or a magnet with other moving charged objects or another magnet.<br>• the magnetic properties of some materials can be a affected by magnetic fields at the system.<br>• changing magnetic flux induces an electric field that can establish an induced emf in a system. | • describe the orientation of a magnetic dipole placed in a magnetic field applying the right hand rule.<br>• create a verbal or visual representation of a magnetic eld around a long straight wire or a pair of parallel wires<br>• apply mathematical routines to express the force exerted on a moving charged object by a magnetic field.<br>• use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material.<br>• plan a data collection strategy appropriate to<br>• an investigation of the direction of the force on a moving electrically charged object caused by current in a wire<br>• use representations and models to qualitatively describe the magnetic properties of some materials that can be a affected by magnetic properties of other objects (electromagnets) in the system.<br>• construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop |

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| **Assessments:** | • Lab Reports,<br>• Formative Assessment Problem Sets<br>• Electromagnetism Formative Assessments |
| **Teacher Resources:** | Unit implementation Guide, *Physics* Walker 3rd edition<br>AP Physics 1 and 2 Inquiry-Based Lab Investigations<br>Lab equipment including meters, power supplies, powerful magnets, solenoids<br>Department Lab Report rubric, Phet simulations (available online) |

| Unit Title | Waves and Optics | Length of Unit | 4-5 weeks |
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| Inquiry Questions (Engaging & Debatable) | • How do we know the arrangement of atoms in a crystal?<br>• How do small projectors produce large images?<br>• Why do objects appear closer when they are in the water? |
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| **Standards*** | **Big Idea:** 6<br>**Learning Objective:** 6.A.1; 6.B.3; 6.C.1; 6.C.2; 6.C.3; 6.E.1; 6.E.2; 6.E.3; 6.E.5; 6.F.1 |
| **Unit Strands & Concepts** | • Measure and explain the interference patterns caused by narrow slits and crystals.<br>• Set up experiments to find focal lengths, image distances and wavelengths. |
| **Key Vocabulary** | refraction, reflection, propagation, diffraction, interference, superposition, focus |

| Unit Title | Waves and Optics | Length of Unit | 4-5 weeks |
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| Critical Content: My students will Know... | Key Skills: My students will be able to (Do)... |
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| ● Waves can propagate via different oscillation modes such as transverse and longitudinal.<br>● simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave.<br>● When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.<br>● When waves pass through an opening whose dimensions are comparable to the wavelength, a diffraction pattern can be observed.<br>● When waves pass through a set of openings whose spacing is comparable to the wavelength, an interference pattern can be observed.<br>● When light travels from one medium to another, some of the light is transmitted, some is re ected, and some is absorbed.<br>● When light hits a smooth reflecting surface at an angle, it reflects at the same angle on the other side of the line perpendicular to the surface; this law of reflection | ● analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation<br>● construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa<br>● construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.<br>● make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave.<br>● qualitatively apply the wave model to quantities that describe the generation of interference patterns to make predictions about interference patterns that form when waves pass through set of openings whose spacing and widths are small compared to the wavelength of the waves. |

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| accounts for the size and location of images seen in mirrors.<br>● When light travels across a boundary from one transparent material to another, the speed of propagation changes. At a non- normal incident angle, the path of the light ray bends closer to the perpendicular in the optically slower substance. This is called refraction.<br>● The refraction of light as it travels from one transparent medium to another can be used to form images.<br>● Types of electromagnetic radiation are characterized by their wavelengths, and certain ranges of wavelength have been given specific names. These include (in order of increasing wavelength spanning a range from picometers to kilometers) gamma rays, x-rays, ultraviolet, visible light, infrared, microwaves, and radio waves. | ● make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is re ected, and some is absorbed.<br>● make predictions about the locations of object and image relative to the location of a reflecting surface.<br>● plan data collection strategies as well as perform data analysis and evaluation of the evidence for nding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law)<br>● use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses.<br>● make qualitative comparisons of the wavelengths of types of electromagnetic radiation. |

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| **Assessments:** | • Lab Reports, Formative Assessments, Problem Sets<br>• Optics Tests |
| **Teacher Resources:** | Unit implementation Guide, *Physics* Walker 3rd edition, AP Physics 1 and 2 Inquiry-Based Lab Investigations<br>Lab equipment including optics benches, lasers, diffraction plates and gratings, lenses, mirrors<br>Department Lab Report rubric, Phet simulations |

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| **Unit Title** | Modern Physics | **Length of Unit** | 5-6 weeks |

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| **Inquiry Questions** **(Engaging & Debatable)** | • How can a photon have momentum but no mass?<br>• How can electrons be used to produce diffraction patterns to determine the shapes of crystals?<br>• Why are only specific wavelengths of light absorbed or emitted? How can this be used to identify the composition of a substance?<br>• How can a small amount of material be used by a nuclear plant to generate a large amount of energy? |
| **Standards*** | **Big Ideas:** 1, 3, 5, 6, 7<br>**Learning Objectives:** 1.A.2; 1.A.4; 1.D.1; 1.D.3; 3.G.3; 4.C.4; 5.B.8; 5.C.1; 5.G.1; 6.F.3; 6.F.4; 6.G.2; 7.C.1; 7.C.2; 7.C.3; 7.C.4 |
| **Unit Strands & Concepts** | • Explain the photoelectric effect using quantum concepts.<br>• Analyze the transitions in spectral data.<br>• Determine the energy used to hold nuclei together by applying mass energy and the strong force.<br>• Evaluate the results of collisions involving electrons and photons. |
| **Key Vocabulary** | Photon, Quanta, Radioactive, Alpha Particle, Beta Particle, Gamma Particle, Wave model, Particle Model, Relativity, Stopping potential, Work Function, Photoelectric Effect, Energy Level, Ground State, Ionization |

| **Unit Title** | Modern Physics | **Length of Unit** | 5-6 weeks |
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| **Critical Content:**<br>**My students will Know...** | **Key Skills:**<br>**My students will be able to (Do)...** |
| --- | --- |
| • fundamental particles have no internal structure.<br>• atoms have internal structures that determine their properties.<br>• objects classically thought of as particles can exhibit properties of waves.<br>• properties of space and time cannot always be treated as absolute.<br>• the strong force is exerted at nuclear scales and dominates the interactions of nucleons.<br>• mass can be converted into energy, and energy can be converted into mass.<br>• energy transfer occurs when photons are absorbed or emitted, for example, by atoms or nuclei.<br>• electric charge is conserved in nuclear and elementary particle reactions, even when elementary particles are produced or destroyed.<br>• the possible nuclear reactions are constrained by the law of conservation of nucleon number. | • construct representations of the differences between a fundamental particle and a system composed of fundamental particles and to relate this to the properties and scales of the systems being investigated.<br>• construct representations of the energy-level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated.<br>• explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.<br>• articulate the reasons that classical mechanics must be replaced by special relativity to describe the experimental results and theoretical predictions that show that the properties of space and time are not absolute.<br>• identify the strong force as the force that is responsible for holding the nucleus together.<br>• apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.<br>• describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including |

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| ● photons are individual energy packets of electromagnetic waves, with *Ephoton hf* where *h* is Planck's constant and *f* is the frequency of the associated light wave.<br>● nature of light requires that different models of light are most appropriate at different scales.<br>● certain regimes of energy or distance, matter can be modeled as a wave. The behavior in these regimes is described by quantum mechanics.<br>● the probabilistic description of matter is modeled by a wave function, which can be assigned to an object and used to describe its motion and interactions. The absolute value of the wave function is related to the probability of nding a particle in some spatial region.<br>● the allowed states for an electron in an atom can be calculated from the wave model of an electron.<br>● the spontaneous radioactive decay of an individual nucleus is described by probability.<br>● photon emission and absorption processes are described by probability | characterization of the frequency of radiation emitted or absorbed.<br>● analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge.<br>● apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.<br>● support the photon model of radiant energy with evidence provided by the photoelectric effect.<br>● select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter.<br>● articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the di raction of matter interacting with a crystal, given conditions where a particle of matter has momentum corresponding to a de Broglie wavelength smaller than the separation between adjacent atoms in the crystal.<br>● use a graphical wave function representation of a particle to predict qualitatively the probability of nding a particle in a specific spatial region.<br>● use a standing wave model in which an electron orbit circumference is an integer multiple of the de Broglie wavelength to give a qualitative explanation that accounts for the existence of specific allowed energy states of an electron in an atom.<br>● The student is able to predict the number of radioactive nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay.<br>● construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. |

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| **Assessments:** | • Lab Reports, Formative Assessments, Problem Sets<br>• Modern Physics Tests |
| **Teacher Resources:** | Unit implementation Guide, *Physics* Walker 3rd edition<br>AP Physics 1 and 2 Inquiry-Based Lab Investigations<br>Lab equipment including optics benches, lasers, diffraction plates and LEDs<br>Department Lab Report rubric, Phet simulations (available online) |