ADVANCED PLACEMENT PHYSICS II

Students explore principles of fluids, thermodynamics, electricity, magnetism, optics, and topics in modern physics. The course is based on seven Big Ideas, which encompass core scientific principles, theories, and processes that cut across traditional boundaries and provide a broad way of thinking about the physical world.

BIG IDEA 1: *Objects and systems have properties such as mass and charge. Systems may have internal structure.*

The student is able to model verbally or visually the properties of a system based on its substructure (electron configuration) and to relate this to changes in the system properties over time as external variables are changed. These properties include mass and charge (resistivity). [SP 1.1, 4.1, 7.1]

The student is able to make claims, discuss, explain, and make predictions about natural phenomena (such as charging process and simple circuits) based on conservation of electric charge. [SP 1.5, 6.1, 6.2, 6.4, 7.2]

The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration and to distinguish between inertial and gravitational mass. [SP 4.2]

The student is able to explain why classical mechanics cannot describe all properties of objects and articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass-energy. [SP 1.5, 6.1, 6.3, 7.1, 7.2]

The student is able to predict the densities for natural phenomena, design an investigation to verify the prediction, and evaluate the experimental data necessary to determine an object's density. [SP 4.1, 4.2, 6.4]

BIG IDEA 2: *Fields existing in space can be used to explain interactions.*

The student is able to qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field. [SP 2.2, 6.4, 7.2]

The student is able to explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object. [SP 6.2]

The student is able to distinguish the characteristics that differ between monopole fields and dipole fields and make claims about the spatial behavior of the fields using qualitative or semi-quantitative arguments. [SP 2.2, 6.4, 7.2]

The student is able to apply mathematical routines to determine the magnitude and direction of the electric field created by different configurations of point charges and/or charged plates. [SP 1.4, 2.2, 6.2]

The student is able to 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. [SP 1.1, 2.2, 7.1]

The student is able to predict, construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential. [SP 1.4, 6.4, 7.2]

The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. [SP 2.2]

The student is able to qualitatively and quantitatively describe, or create a visual representation of a magnetic field around a bar magnet, a long straight wire, or a pair of parallel wires. [SP 1.1, 1.2]

The student is able to use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material. [SP 1.4]

The student is able to qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and quantitatively determine the electric field at a location and the effect of that field on electrically charged objects. [SP 1.4, 6.4, 7.2]

The student is able to apply mathematical routines to relate isolines to electric field strength. [SP 2.2]

BIG IDEA 3: *The interactions of an object with other objects can be described by forces.*

The student is able to analyze, discuss, and predict (both qualitatively and quantitatively) the motion of an object subject to forces exerted by one or several objects using an application of Newton's three laws in a variety of physical situations including translational motion and oscillating systems. [SP 1.1, 1.4, 1.5, 2.2, 6.4, 7.2]

The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [SP 7.2]

The student is able to qualitatively and quantitatively use mathematics to describe the electric force that results from the interaction of two or more point charges. [SP 2.2, 6.4]

The student is able to determine the direction of the magnetic force exerted on the charged object due to the magnetic field. [SP 1.4]

The student is able to design an experiment to investigate the direction of the force on a moving electrically charged object in a magnetic field near a current-carrying wire. [SP 4.2, 5.1]

The student is able to make claims and explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.1, 6.2]

The student is able to identify and discuss the strength of each of the four forces in a given situation (gravitational, electromagnetic, strong nuclear and weak nuclear) and predict the motion of the objects they act upon. [SP 7.1]

The student is able to identify the strong force as the force that is responsible for holding the nucleus together. [SP 7.2]

BIG IDEA 4: *Interactions between systems can result in changes in those systems.*

The student is able to predict and explain heat flow between due to temperature differences based on interactions at the microscopic level. [SP 6.4]

The student is able to quantitatively describe the relationship between mass and energy and apply this concept. [SP 2.2, 2.3, 7.2]

The student is able to use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by magnetic properties of other objects in the system. [SP 1.1, 1.4, 2.2]

The student is able to explain devices using Faraday’s law in different scenarios. [SP 6.4]

The student is able to discuss and predict the redistribution of charge (qualitatively and with a diagram) in insulators and conductors caused by friction, conduction, induction, and exposure to an electric field. [SP 1.1, 1.4, 6.4, 7.2]

The student is able to plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. [SP 3.2, 4.1, 4.2, 5.1, 5.3]

The student is able to analyze, discuss and predict the properties of resistors and/or capacitors in a simple circuit. [SP 2.2, 6.4]

The student is able to make and justify predictions (qualitatively and quantitatively) of the effect 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. [SP 2.2, 6.1, 6.4]

The student is able to design an experiment and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. [SP 2.2, 4.2, 5.1]

BIG IDEA 5: *Changes that occur as a result of interactions are constrained by conservation laws.*

The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. [SP 1.4, 2.1]

The student is able to describe, predict and calculate the internal energy of a system and changes in the system's kinetic and potential energies due to interactions between the system and its environment with either forces or temperature gradients. [SP 1.4, 2.1, 2.2, 6.4, 7.2]

The student is able to create and 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 first law of thermodynamics). [SP 1.1, 1.4, 2.2]

The student is able to describe and calculate emission or absorption spectra associated with electronic or nuclear. [SP 1.2, 7.2]

The student is able to analyze experimental data including analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff's loop rule. [SP 5.1]

The student is able to use graphical and symbolic representations to describe and make predictions regarding electrical potential difference, charge, power, and current in steady-state circuits composed of various combinations of resistors and capacitors. [SP 1.5, 6.4]

The student is able to mathematically evaluate electric potential energy and current in a multi-loop electrical circuit. [SP 2.1, 2.2, 4.1, 4.2, 5.1, 5.3]

The student is able to refine and analyze an experiment for circuits that include batteries with internal resistance and a non-ohmic resistor. [SP 4.1, 4.2, 5.1, 5.3]

The student is able to use Bernoulli's equation to make calculations related to a moving fluid. [SP 2.2]

The student is able to use Bernoulli's equation, the relationship between force and pressure, conservation of energy, and/or the continuity equation to make calculations related to a moving fluid. [SP 2.2, 6.2]

The student is able to apply conservation of mass and conservation of energy concepts to a natural phenomenon and use the equation $E = mc^2$ to make a related calculation. [SP 2.2, 7.2]

The student is able to analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge. [SP 6.4, 7.2]

The student is able to design an experiment, analyze the data, and justify the selection of data relevant to an investigation on the electrical charging of objects and electric charge induction on neutral objects. [SP 4.1, 4.2, 5.1, 6.4]

The student is able to predict or explain current values in circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation. [SP 1.4, 2.2, 6.4, 7.2]

The student is able to determine missing values and direction of electric current in branches of a circuit with resistors and capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. [SP 1.4, 2.2]

The student is able to 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. [SP 1.4, 2.2]

The student is able to predict the properties of a colliding system and classify collisions as elastic or inelastic. [SP 2.1, 2.2, 6.4, 7.2]

The student is able to make predictions about the velocity of the center of mass for interactions within a defined one-dimensional or two-dimensional system. [SP 6.4]

The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). [SP 2.1, 2.2, 7.2]

The student is able to 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. [SP 6.4]

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.*

The student is able to describe the types of waves and 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. [SP 5.1, 6.2]

The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation. [SP 6.4, 7.2]

The student is able to construct an equation relating the wavelength and amplitude of a wave from a graphical representation, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation. [SP 1.5]

The student is able to make claims and predictions and construct representations of waves to graphically analyze situations in which two waves overlap over time using the principle of superposition. [SP 1.4, 6.4, 7.2]

The student is able to evaluate and predict a diffraction pattern produced when a wave passes through a small opening. [SP 1.4, 6.4, 7.2]

The student is able to 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 a set of openings whose spacing and widths are small compared to the wavelength of the waves. [SP 1.4, 6.4]

The student is able to predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light. [SP 6.4, 7.2]

The student is able to make claims about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. [SP 6.4, 7.2]

The student is able to make predictions about the locations of object and image relative to the location of a reflecting surface. [SP 6.4, 7.2]

The student is able to plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding 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). [SP 4.1, 5.1, 5.2, 5.3]

The student is able to describe models and make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. (Snell's Law) [SP 1.1, 1.4, 6.4, 7.2]

The student is able to design an experiment and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from flat and curved spherical mirrors. [SP 3.2, 4.1, 5.1, 5.2, 5.3]

The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces and due to refraction of light through lenses. [SP 1.4, 2.2]

The student is able to design an experiment an, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses. [SP 3.2, 4.1, 5.1, 5.2, 5.3]

The student is able to describe representations and models of electromagnetic waves and explain the transmission of energy when no medium is present. [SP 1.1, 6.4, 7.2]

The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate. [SP 6.4, 7.1]

The student is able to articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the diffraction 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. [SP 6.1]

The student is able to predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima), based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal. (de Broglie wavelength need not be given, so students may need to obtain it.) [SP 6.4]

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.*

Treating a gas molecule as an object, the student is able to 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. [SP 1.4, 2.2, 6.4, 7.2]

The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes. [SP 7.1]

The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. [SP 6.4, 7.2]

The student is able to 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. [SP 3.2, 4.2]

The student is able to 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 $PV = nRT$. [SP 5.1]

The student is able to 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. [SP 7.1]

The student is able to use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region. [SP 1.4]

The student is able to 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. [SP 1.4]

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. [SP 6.4]

The student is able to construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. [SP 1.1, 1.2]

Science Practice for AP Physics II

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

1.1. The student can create representations and models of natural or man-made phenomena and systems in the domain.
1.2. The student can describe representations and models of natural or man-made phenomena and systems in the domain.
1.3. The student can refine representations and models of natural or man-made phenomena and systems in the domain.
1.4. The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
1.5. The student can re-express key elements of natural phenomena across multiple representations in the domain.

Science Practice 2: The student can use mathematics appropriately.

2.1 The student can justify the selection of a mathematical routine to solve problems.
2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
2.3 The student can estimate numerically quantities that describe natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

3.1 The student can pose scientific questions.
3.2 The student can refine scientific questions.
3.3 The student can evaluate scientific questions.

Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question. [Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction, and/or archived data.]

4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question.
4.2 The student can design a plan for collecting data to answer a particular scientific question.
4.3 The student can collect data to answer a particular scientific question.
4.4 The student can evaluate sources of data to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

5.1 The student can analyze data to identify patterns or relationships.
5.2 The student can refine observations and measurements based on data analysis.
5.3 The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories.

6.1 The student can justify claims with evidence.
6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.
6.3 The student can articulate the reasons that scientific explanations and theories are refined or replaced.
6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.
6.5 The student can evaluate alternative scientific explanations.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

7.1 The student can connect phenomena and models across spatial and temporal scales.
7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.