Glen Ridge Board of Education
Science
AP Physics II
Required
Full Year

New Jersey Student Learning Standards

Written by: Timothy Panebianco
Science Mission Statement:

The Glen Ridge Public School’s science curriculum seeks to inspire scientifically-literate citizens who will be able to participate in a dynamic global community. Our program fosters a spirit of intellectual curiosity and collaborative problem solving that is innovative, experiential, thought-provoking, and developmentally appropriate. Our students will use scientific methodology to evaluate and critique global issues relating to Life Sciences, Physical Sciences, The Sciences of Earth & Space, and Engineering Sciences. Students will be challenged and will be encouraged to take risks and develop critical scientific thinking skills.

Course Description: AP Physics 1 is an elective course for 11th, and 12th grade students.

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<td>Unit 1: Fluids</td>
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Time Allotted (days of instruction): 15 days

New Jersey Student Learning Standards (NJSLS):

This unit provides necessary background and skills for the following units.

### AP Physics 1 and 2 Standards:

- Essential Knowledge 1.E.1: Matter has a property called density.
- Learning Objective (1.E.1.1): The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.
- Learning Objective (1.E.1.2): The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
- Essential Knowledge 5.B.10: Bernoulli’s equation describes the conservation of energy in fluid flow.
- Learning Objective (5.B.10.1): The student is able to use Bernoulli’s equation to make calculations related to a moving fluid.
- Learning Objective (5.B.10.2): The student is able to use Bernoulli’s equation and/or the relationship between force and pressure to make calculations related to a moving fluid.
- Learning Objective (5.B.10.3): The student is able to use Bernoulli’s equation and the continuity equation to make calculations related to a moving fluid.
- Learning Objective (5.B.10.4): The student is able to construct an explanation of Bernoulli’s equation in terms of the conservation of energy.
- Essential Knowledge 3.C.4: Contact forces result from the interaction of one object touching another object and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).
- Learning Objective (3.C.4.2): The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.

### Essential Questions

- How is density defined?
- Density
- Specific Gravity

### Student Learning Objectives

- Density, Specific Gravity
- Pressure
| What is the difference between gauge pressure and absolute pressure? | Pressure in Fluids |
| How do hydraulic lifts work? | Atmospheric Pressure and Gauge Pressure |
| What is the buoyant force? | Pascal’s Principle |
| How do water speeds vary in pipes? | Buoyancy and Archimedes’ Principle |

### Resources/Materials

### Interdisciplinary Connections
- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

### 21st Century Life and Careers
- **Standard 6.3 Active Citizenship in the 21st Century**
  - All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

- **Standard 9.1 21st-Century Life & Career Skills**
  - All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures

### Technology Standards
- **Standard 8.1 – Computer and Information Literacy**
  - All students will use computer applications to gather and organize information and to solve problems.
### Assessments

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### Modifications

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### Time Allotted (days of instruction): 10 days

**New Jersey Student Learning Standards (NJSLS):**
- ● Exceeds Standards

**AP Physics 1 and 2 Standards:**
- ● **Essential Knowledge 6.E.2:** 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 (specular reflection); and this law of reflection accounts for the size and location of images seen in plane mirrors.
- ● **Learning Objective (6.E.2.1):** The student is able to make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface.
- ● **Essential Knowledge 6.E.3:** 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.
  a. Snell’s law relates the angles of incidence and refraction to the indices of refraction, with the ratio of the indices of refraction inversely proportional to the ratio of the speeds of propagation in the two media.
  b. When light travels from an optically slower substance into an optically faster substance, it bends away from the perpendicular.
  c. At the critical angle, the light bends far enough away from the perpendicular that it skims the surface of the material.
  d. Beyond the critical angle, all of the light is internally reflected. **Learning Objective (6.E.3.1):** The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.
- Learning Objective (6.E.3.2): 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).
- Learning Objective (6.E.3.3): The student is able to 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.
- Essential Knowledge 6.E.4: The reflection of light from surfaces can be used to form images.
  a. Ray diagrams are very useful for showing how and where images of objects are formed for different mirrors, and how this depends upon the placement of the object. Concave and convex mirror examples should be included.
  b. They are also useful for determining the size of the resulting image compared to the size of the object.
  c. Plane mirrors, convex spherical mirrors, and concave spherical mirrors are part of this course. The construction of these ray diagrams and comparison with direct experiences are necessary.
- Learning Objective (6.E.4.1): The student is able to plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors.
- Learning Objective (6.E.4.2): 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. Essential Knowledge 6.E.5: The refraction of light as it travels from one transparent medium to another can be used to form images.
  a. Ray diagrams are used to determine the relative size of object and image, the location of object and image relative to the lens, the focal length, and the real or virtual nature of the image. Converging and diverging lenses should be included as examples.
- Learning Objective (6.E.5.1): 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 refraction of light through thin lenses.
- Learning Objective (6.E.5.2): The student is able to plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses.

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<td>How light reflects and refracts on and through surfaces. How to draw ray diagrams to find the location of an image.</td>
<td>Reflection and Mirrors Refraction and Snell’s Law Thin Lenses SMART Response multiple choice questions Problem solving in groups</td>
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Time Allotted (days of instruction): 16 days

New Jersey Student Learning Standards (NJSLS):
- HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

AP Physics 1 and 2 Standards:
- Essential Knowledge 4.C.3: Energy is transferred spontaneously from a higher temperature system to a lower temperature system. This process of transferring energy is called heating. The amount of energy transferred is called heat.
  a. Conduction, convection, and radiation are mechanisms for this energy transfer.
  b. At a microscopic scale the mechanism of conduction is the transfer of kinetic energy between particles.
  c. During average collisions between molecules, kinetic energy is transferred from faster molecules to slower molecules.
- Learning Objective 4.C.3.1: The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level.
- Essential Knowledge 5.B.2: A system with internal structure can have internal energy, and changes in a system’s internal structure can result in changes in internal energy. [Physics 1: includes mass-spring oscillators and simple pendulums. Physics 2: includes charged object in electric fields and examining changes in internal energy with changes in configuration.]
- Learning Objective 5.B.2.1: 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.
- Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.
  a. Since energy is constant in a closed system, changes in a system’s potential energy can result in changes to the system’s kinetic energy.
  b. The changes in potential and kinetic energies in a system may be further constrained by the construction of the system.
- Learning Objective 5.B.4.1: The student is able to describe and make predictions about the internal energy of systems.
- Learning Objective 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system using information from representations of that system.
- Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.
- Learning Objective 5.B.5.1: The student is able to design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.
- Learning Objective 5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).
- Learning Objective 5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.
- **Learning Objective 5.B.5.6:** The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system.

- **Essential Knowledge 5.B.6:** Energy can be transferred by thermal processes involving differences in temperature; the amount of energy transferred in this process of transfer is called heat.

- **Learning Objective 5.B.6.1:** The student is able to 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.

- **Essential Knowledge 5.B.7:** 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 should include P-V diagrams — isovolumetric processes, isothermal processes, isobaric processes, and adiabatic processes. No calculations of internal energy change from temperature change are required; in this course, examples of these relationships are qualitative and/or semiquantitative.

- **Learning Objective 5.B.7.1:** The student is able to 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.

- **Learning Objective 5.B.7.2:** The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.

- **Learning Objective 5.B.7.3:** The student is able to 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).

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<td>The concept of temperature and thermal equilibrium</td>
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<td>How is thermal energy transferred between systems?</td>
<td>Phase transitions</td>
<td>Heat, Thermal Equilibrium</td>
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<tr>
<td>How are heat and work related to internal energy?</td>
<td>The ideal gas law</td>
<td>Phase Transitions &amp; Heat Transfer</td>
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<tr>
<td>How are temperature, pressure, and volume of an ideal gas related?</td>
<td>Kinetic theory</td>
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**Resources/Materials**


**Interdisciplinary Connections**

N-VM A. Represent and model with vector quantities

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A-SSE B. Write expressions in equivalent forms to solve problems
A-CED A. Create equations that describe numbers or relationships
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A-REI B. Solve equations and inequalities on one variable
A-REI C. Solve systems of equations
A-REI D. Represent and solve equations and inequalities graphically

21st Century Life and Careers

Standard 6.3 Active Citizenship in the 21st Century
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New Jersey Student Learning Standards (NJSLS):

- **HS-PS2-4.** Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.

AP Physics 1 and 2 Standards:

- **Essential Knowledge 1.B.1:** Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
  a. An electrical current is a movement of charge through a conductor.
  b. A circuit is a closed loop of electrical current.
- **Learning Objective: 1.B.1.1:** The student is able to make claims about natural phenomena based on conservation of electric charge.
- **Learning Objective: 1.B.1.2:** The student is able to 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, including conservation of charge in simple circuits.
- **Essential Knowledge 1.B.2:** 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.
  a. Like-charged objects and systems repel, and unlike-charged objects and systems attract.
  b. Charged objects or systems may attract neutral systems by changing the distribution of charge in the neutral system.
- **Learning Objective 1.B.2.1:** The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.
- **Learning Objective 1.B.2.2:** The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.
- **Learning Objective 1.B.2.3:** The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object.
- **Essential Knowledge 1.B.3:** The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
  a. The magnitude of the elementary charge is equal to $1.6 \times 10^{-19}$ coulombs.
  b. Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron.
- **Learning Objective 1.B.3.1:** The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.
- **Essential Knowledge 2.A.1:** A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.
  a. Vector fields are represented by field vectors indicating direction and magnitude.
  b. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition.
  c. Conversely, a known vector field can be used to make inferences.
- **Essential Knowledge 2.C.1:** The magnitude of the electric force $F$ exerted on an object with electric charge $q$ by an electric field is $F=QE$. The direction of the force is determined by the direction of the field and the sign of the charge, with positively charged objects accelerating in the direction of the field and
negatively charged objects accelerating in the direction opposite the field. This should include a vector field map for positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

- **Learning Objective 2.C.1.1:** The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge $q$ placed in an electric field $E$ using the mathematical model of the relation between an electric force and an electric field: $F = qE$; a vector relation.

- **Learning Objective 2.C.1.2:** The student is able to 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.

- **Essential Knowledge 2.C.2:** The magnitude of the electric field vector is proportional to the net electric charge of the object(s) creating that field. This includes positive point charges, negative point charges, spherically symmetric charge distributions, and uniformly charged parallel plates.

- **Learning Objective 2.C.2.1:** The student is able to qualitatively and semiquantitatively apply the vector relationship between the electric field and the net electric charge creating that field.

- **Essential Knowledge 2.C.3:** 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. Electric field lines are not in the curriculum. Students will be expected to rely only on the rough intuitive sense underlying field lines, wherein the field is viewed as analogous to something emanating uniformly from a source.
  a. The inverse square relation known as Coulomb’s law gives the magnitude of the electric field at a distance $r$ from the center of a source object of electric charge $Q$ as $E = \frac{KQ}{r^2}$.
  b. This relation is based on a model of the space surrounding a charged source object by considering the radial dependence of the area of the surface of a sphere centered on the source object.

- **Learning Objective 2.C.3.1:** The student is able to explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object.

- **Essential Knowledge 2.C.4:** 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. Electric dipoles are treated qualitatively in this course as a teaching analogy to facilitate student understanding of magnetic dipoles.
  a. When an object is small compared to the distances involved in the problem, or when a larger object is being modeled as a large number of very small constituent particles, these can be modeled as charged objects of negligible size, or “point charges.”
  b. The expression for the electric field due to a point charge can be used to determine the electric field, either qualitatively or quantitatively, around a simple, highly symmetric distribution of point charges.

- **Learning Objective 2.C.4.1:** The student is able to 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) and make claims about the spatial behavior of the fields using qualitative or semiquantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field.

- **Learning Objective 2.C.4.2:** The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points.

- **Essential Knowledge 2.C.5:** 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.
• **Learning Objective 2.C.5.1:** The student is able to create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs and is able to recognize that the assumption of uniform field is not appropriate near edges of plates.

• **Learning Objective 2.C.5.2:** The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.

• **Learning Objective 2.C.5.3:** 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.

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</table>
| Why is it that when you take off a sweater in a dark room you can see tiny sparks and hear a crackling sound? | • The two types of electric charges  
• The law of conservation of charge  
• How charges interact  
• How to charge various object using conduction  
• Use Coulomb’s Law to solve problems  
• Make predictions about charges | • Electric Charge  
• Conduction, induction, and the electroscope  
• Electric force in 2D  
• Electric and gravitational fields  
• Electric field in 2D  
• Electric Charge Demos  
• SMART Response multiple choice questions  
• Problem solving in groups |
| A student touches an electroscope with his hand at the same time he brings a positively charged rod close to the electroscope without touching. When he removes his hand first and then moves the rod away from the electroscope the leaves move apart. Why? What type of charge is on the leaves? | | |
| What is the definition of the Electric Field and what equation was used to derive this concept? | | |
| Why can Electric Field lines never cross or touch each other? Do Electric Field lines exist? | | |

---

**Resources/Materials**

Online textbook, homework, quizzes, tests and labs:  

**Interdisciplinary Connections**

N-VM A. Represent and model with vector quantities
### 21st Century Life and Careers

**Standard 6.3 Active Citizenship in the 21st Century**

All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

**Standard 9.1 21st-Century Life & Career Skills**

All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

### Technology Standards

**Standard 8.1 – Computer and Information Literacy**

All students will use computer applications to gather and organize information and to solve problems.

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<tbody>
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<tr>
<td>● Electric Field Quiz</td>
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<tr>
<td>● Free Response Quiz</td>
</tr>
<tr>
<td>● SMART Response multiple choice questions</td>
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</tr>
<tr>
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<tr>
<td>● Video lectures</td>
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</tbody>
</table>
## AP Physics 2
### Unit 5: Electric Potential and Capacitors

**Time Allotted (days of instruction): 12 days**

**New Jersey Student Learning Standards (NJSLS):**
- HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.

**AP Physics 1 and 2 Standards:**
- **Essential Knowledge 2.A.2:** A scalar field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a scalar. In Physics 2, this should include electric potential.
  - a. Scalar fields are represented by field values.
  - b. When more than one source object with mass or charge is present, the scalar field value can be determined by scalar addition.
  - c. Conversely, a known scalar field can be used to make inferences about the number, relative size, and location of sources.
- **Learning Objective 2.C.5.2:** The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.
- **Essential Knowledge 2.E.1:** Isolines on a topographic (elevation) map describe lines of approximately equal gravitational potential energy per unit mass (gravitational equipotential). As the distance between two different isolines decreases, the steepness of the surface increases. [Contour lines on topographic maps are useful teaching tools for introducing the concept of equipotential lines. Students are encouraged to use the analogy in their answers when explaining gravitational and electrical potential and potential differences.]
- **Learning Objective 2.E.1.1:** The student is able to 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.
- **Essential Knowledge 2.E.2:** Isolines in a region where an electric field exists represent lines of equal electric potential referred to as equipotential lines.
  - a. An isoline map of electric potential can be constructed from an electric field vector map, using the fact that the isolines are perpendicular to the electric field vectors.
  - b. Since the electric potential has the same value along an isoline, there can be no component of the electric field along the isoline.
- **Learning Objective 2.E.2.1:** The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field.
- **Learning Objective 2.E.2.2:** The student is able to predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field.
- **Learning Objective 2.E.2.3:** The student is able to 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.
- **Essential Knowledge 2.E.3:** 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.
- **Learning Objective 2.E.3.1:** The student is able to 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.
- **Learning Objective 2.E.3.2:** The student is able to apply the concept of the isoline representation of electric potential for a given electric charge distribution to predict the average value of the electric field in the region.
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<th>Student Learning Objectives</th>
<th>Activities</th>
</tr>
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</table>
| • What is the definition of the Electric Field and what equation was used to derive this concept?  
• Why can Electric Field lines never cross or touch each other? Do Electric Field lines exist?  
• What is the significance of the density of the electric field lines about a charge?  
• How is the Electric Potential derived from the Electric Potential Energy?  
• What is an equipotential line? How does it relate to an Electric Field line? | • How to define electric fields and how they relate to electric force.  
• The relationship between electric potential, voltage and potential energy.  
• How charged objects respond to electric fields and potential differences.  
• Use Coulomb’s Law to solve problems  
• Make predictions about charges                                                                                                               | • Electric Potential Energy  
• Electric Potential  
• Uniform Electric Field  
• Voltage  
• Capacitance and Capacitors  
• Potential and Capacitance Lab  
• SMART Response multiple choice questions  
• Problem solving in groups |

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A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning  
A-REI B. Solve equations and inequalities on one variable  
A-REI C. Solve systems of equations  
A-REI D. Represent and solve equations and inequalities graphically |                                                                                                                 |                                                                                                         |

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### Technology Standards

**Standard 8.1 – Computer and Information Literacy**

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● Electric Potential Quiz  
● Electric Potential Energy Quiz  
● Capacitance Quiz  
● Free Response Quiz  
● SMART Response multiple choice questions | ● Electric Potential and Capacitance Test | ● Marzano scales | ● Not applicable |

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● Lecture notes provided  
● Video lectures | ● Preferential group seating  
● Extended time  
● Lecture notes provided  
● Homework posted online daily | ● Lead content or problem reviews  
● Tutor other students  
● Leadership in cooperative groups  
● Review same topic AP Physics C |

### AP Physics 2

**Unit 6: Electric Current and Circuits**

#### Time Allotted (days of instruction): 15 days

- **New Jersey Student Learning Standards (NJSLS):** This unit provides necessary background and skills for the following units.

- **AP Physics 1 and 2 Standards: Essential Knowledge 1.B.1:** Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
  a. An electrical current is a movement of charge through a conductor.
  b. A circuit is a closed loop of electrical current.

- **Learning Objective: 1.B.1.1:** The student is able to make claims about natural phenomena based on conservation of electric charge.

- **Learning Objective: 1.B.1.2:** The student is able to 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, including conservation of charge in simple circuits.
**Essential Knowledge 4.E.4:** 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.

a. The resistance of a resistor is proportional to its length and inversely proportional to its cross-sectional area. The constant of proportionality is the resistivity of the material.

b. The capacitance of a parallel plate capacitor is proportional to the area of one of its plates and inversely proportional to the separation between its plates. The constant of proportionality is the product of the dielectric constant, \( k \), of the material between the plates and the electric permittivity, \( \varepsilon \).

c. The current through a resistor is equal to the potential difference across the resistor divided by its resistance.

d. The magnitude of charge of one of the plates of a parallel plate capacitor is directly proportional to the product of the potential difference across the capacitor and the capacitance. The plates have equal amounts of charge of opposite sign.

**Learning Objective 4.E.4.1:** The student is able to make predictions about the properties of resistors and/or capacitors when placed in a simple circuit based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.

**Learning Objective 4.E.4.2:** The student is able to 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.

**Learning Objective 4.E.4.3:** The student is able to analyze 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.

**Essential Knowledge 4.E.5:** 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.

**Learning Objective 4.E.5.1:** The student is able to make and justify a quantitative prediction 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.

**Learning Objective 4.E.5.2:** The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

**Learning Objective 4.E.5.3:** The student is able to plan data collection strategies 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.

<table>
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<tr>
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<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are voltage, current, and resistance?</td>
<td>That current is defined as charge over time</td>
<td>• Currents and Conductors</td>
</tr>
<tr>
<td>How are voltage, current, and resistance related?</td>
<td>The relationship between voltage, current, and resistance</td>
<td>• Power and Resistivity</td>
</tr>
<tr>
<td>What factors affect resistivity?</td>
<td>Ohm’s Law</td>
<td>• Circuit Diagrams</td>
</tr>
<tr>
<td>What is capacitance?</td>
<td>Kirchhoff’s Rules</td>
<td>• Equivalent Resistance and Measurement</td>
</tr>
</tbody>
</table>

**Activities**

- Currents and Conductors
- Power and Resistivity
- Circuit Diagrams
- Equivalent Resistance and Measurement
- EMF and Terminal Voltage
- Kirchhoff’s Rules
- RC Circuits
- Circuits Lab
- SMART Response multiple choice questions
- The relationship between voltage/current/resistance and power in circuits
- The relationship between emf and terminal voltage
- The rules and applications of capacitance
- Problem solving in groups

**Resources/Materials**


**Interdisciplinary Connections**
- N-VM A. Represent and model with vector quantities
- N-VM B. Perform operations on vectors
- A-SSE B. Write expressions in equivalent forms to solve problems
- A-CED A. Create equations that describe numbers or relationships
- A-REI A. Understand solving equations as a process of reasoning and explaining the reasoning
- A-REI B. Solve equations and inequalities on one variable
- A-REI C. Solve systems of equations
- A-REI D. Represent and solve equations and inequalities graphically

**21st Century Life and Careers**
- **Standard 6.3 Active Citizenship in the 21st Century**
  All students will acquire the skills needed to be active, informed citizens who value diversity and promote cultural understanding by working collaboratively to address the challenges that are inherent in living in an interconnected world.

- **Standard 9.1 21st-Century Life & Career Skills**
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**Technology Standards**
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● Free Response Quiz  
● SMART Response multiple choice questions | ● Current and Circuits Test | ● Marzano scales | ● Not applicable |

### Modifications

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● Extended time  
● Lecture notes provided  
● Homework posted online daily | ● Lead content or problem reviews  
● Tutor other students  
● Leadership in cooperative groups  
● Review same topic AP Physics C |

### AP Physics 2

**Unit 7: Magnetic Field**

**Time Allotted (days of instruction): 9 days**

**New Jersey Student Learning Standards (NJSLS):**

- **HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- **HS-PS3-5.** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**AP Physics 1 and 2 Standards:**

- **Essential Knowledge 1.E.5:** Matter has a property called magnetic permeability.
  a. Free space has a constant value of the permeability that appears in physical relationships.
  b. The permeability of matter has a value different from that of free space.
- **Enduring Understanding 2.A:** A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.
- **Enduring Understanding 2.D:** A magnetic field is caused by a magnet or a moving electrically charged object. Magnetic fields observed in nature always seem to be produced either by moving charged objects or by magnetic dipoles or combinations of dipoles and never by single poles.
- **Essential Knowledge 2.D.1:** The magnetic field exerts a force on a moving electrically charged object. That magnetic force is perpendicular to the direction of velocity of the object and to the magnetic field and is proportional to the magnitude of the charge, the magnitude of the velocity and the magnitude of the magnetic field. It also depends on the angle between the velocity, and the magnetic field vectors. Treatment is quantitative for angles of 0°, 90°, or 180° and qualitative for other angles.
Learning Objective (2.D.1.1): The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field.

Essential Knowledge 2.D.2: The magnetic field vectors around a straight wire that carries electric current are tangent to concentric circles centered on that wire. The field has no component toward the current-carrying wire.
   a. The magnitude of the magnetic field is proportional to the magnitude of the current in a long straight wire.
   b. The magnitude of the field varies inversely with distance from the wire, and the direction of the field can be determined by a right-hand rule.

Learning Objective (2.D.2.1): The student is able to create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires.

Essential Knowledge 2.D.3: A magnetic dipole placed in a magnetic field, such as the ones created by a magnet or the Earth, will tend to align with the magnetic field vector.
   a. A simple magnetic dipole can be modeled by a current in a loop. The dipole is represented by a vector pointing through the loop in the direction of the field produced by the current as given by the right-hand rule.
   b. A compass needle is a permanent magnetic dipole. Iron filings in a magnetic field become induced magnetic dipoles.
   c. All magnets produce a magnetic field. Examples should include magnetic field pattern of a bar magnet as detected by iron filings or small compasses.
   d. The Earth has a magnetic field.

Learning Objective (2.D.3.1): The student is able to describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet.

Essential Knowledge 2.D.4: Ferromagnetic materials contain magnetic domains that are themselves magnets.
   a. Magnetic domains can be aligned by external magnetic fields or can spontaneously align.
   b. Each magnetic domain has its own internal magnetic field, so there is no beginning or end to the magnetic field — it is a continuous loop.
   c. If a bar magnet is broken in half, both halves are magnetic dipoles in themselves; there is no magnetic north pole found isolated from a south pole.

Learning Objective (2.D.4.1): 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.

Essential Knowledge 3.C.3: A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.
   a. Magnetic dipoles have “north” and “south” polarity.
   b. The magnetic dipole moment of an object has the tail of the magnetic dipole moment vector at the south end of the object and the head of the vector at the north end of the object.
   c. In the presence of an external magnetic field, the magnetic dipole moment vector will align with the external magnetic field.
   d. The force exerted on a moving charged object is perpendicular to both the magnetic field and the velocity of the charge and is described by a right-hand rule.

Learning Objective (3.C.3.1): The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.

Learning Objective (3.C.3.2): The student is able to plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion.

Essential Knowledge 3.G.2: Electromagnetic forces are exerted at all scales and can dominate at the human scale.
- Learning Objective (3.G.2.1): The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved.

Enduring Understanding 4.E: The electric and magnetic properties of a system can change in response to the presence of, or changes in, other objects or systems.

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<tr>
<td>• Both Electric and Magnetic Forces will cause objects to repel and attract each</td>
<td>• How to determine the direction of the magnetic field created by a current carrying wire.</td>
<td>• The Nature of Magnetism and Magnetic Fields</td>
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<tr>
<td>other. What is a difference in the origin of these forces?</td>
<td>• How to determine the force exerted by a magnetic field on a moving charged particle or</td>
<td>• Origin and Direction of Magnetic Fields</td>
</tr>
<tr>
<td>• A Magnet has a north and a south pole. If you cut the magnet in half, describe</td>
<td>current carrying wire.</td>
<td>• Magnetic Force on a Moving Charge</td>
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<td>what happens to each end of the two pieces.</td>
<td>• What Field circles a current carrying wire?</td>
<td>• Magnetic Force on a Current Carrying Wire</td>
</tr>
<tr>
<td>• Can you find a magnet with just a north pole?</td>
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<td>• Magnetic Force Discovery Lab</td>
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<td>• What Field circles a current carrying wire?</td>
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<td>• Magnetic Field due to a long, straight current carrying wire &amp; Magnetic Force between two</td>
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<td>current carrying wires</td>
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<td>• SMART Response multiple choice questions</td>
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<td>● Marzano scales</td>
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<tr>
<td>● Not applicable</td>
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### Modifications

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<tr>
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<th>Special Education/504</th>
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<tbody>
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<tr>
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<tr>
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<tr>
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<tr>
<td>● Review same topic AP Physics C</td>
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</tbody>
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### AP Physics 2

#### Unit 8: Electric Magnetic Induction

**Time Allotted (days of instruction): 9 days**

**New Jersey Student Learning Standards (NJSL) :

- **HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

- **HS-PS3-5.** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 4.E.2: Changing magnetic flux induces an electric field that can establish an induced emf in a system.
  
  a. Changing magnetic flux induces an emf in a system, with the magnitude of the induced emf equal to the rate of change in magnetic flux.
b. When the area of the surface being considered is constant, the induced emf is the area multiplied by the rate of change in the component of the magnetic field perpendicular to the surface.

c. When the magnetic field is constant, the induced emf is the magnetic field multiplied by the rate of change in area perpendicular to the magnetic field.

d. The conservation of energy determines the direction of the induced emf relative to the change in the magnetic flux.

- Learning Objective (4.E.2.1): The student is able to 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 (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Student Learning Objectives</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>- What did Michael Faraday’s experiment demonstrate?</td>
<td>- That an electric current induces a magnetic field.</td>
<td>- Flux and Induced EMF</td>
</tr>
<tr>
<td>- Using Faraday’s Law of Induction, explain how a constant magnetic field can still generate an EMF in a closed loop.</td>
<td>- That a changing magnetic field induces an EMF.</td>
<td>- Faraday’s Law of Induction</td>
</tr>
<tr>
<td>- What is Lenz’s Law?</td>
<td>- How to determine the direction of the induced current.</td>
<td>- Lenz’s Law</td>
</tr>
<tr>
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<td>- EMF Induced in a Moving Conductor</td>
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<tr>
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<td></td>
<td>- Electromagnetic Induction Applications</td>
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## AP Physics 2

### Unit 9: Electromagnetic Waves

**Time Allotted (days of instruction):** 14 days

**New Jersey Student Learning Standards (NJSLS):**
• HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
• HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information.
• HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
• HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
• HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

AP Physics 1 and 2 Standards:
• Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.  
  b. Electromagnetic waves are transverse waves.
• Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.
• Learning Objective (6.A.2.2): The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation.
• Essential Knowledge 6.C.2: When waves pass through an opening whose dimensions are comparable to the wavelength, a diffraction pattern can be observed.
• Essential Knowledge 6.C.3: When waves pass through a set of openings whose spacing is comparable to the wavelength, an interference pattern can be observed. Examples should include monochromatic double-slit interference.
• Learning Objective (6.C.3.1): 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.
• Essential Knowledge 6.C.4: When waves pass by an edge, they can diffract into the “shadow region” behind the edge. Examples should include hearing around corners, but not seeing around them, and water waves bending around obstacles.
• Learning Objective (6.C.4.1): 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.
• Essential Knowledge 6.F.1: 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.
• Learning Objective (6.F.1.1): The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation.
• Essential Knowledge 6.F.2: Electromagnetic waves can transmit energy through a medium and through a vacuum.
  a. Electromagnetic waves are transverse waves composed of mutually perpendicular electric and magnetic fields that can propagate through a vacuum.
  b. The planes of these transverse waves are both perpendicular to the direction of propagation.
• Learning Objective (6.F.2.1): The student is able to describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present.
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<tr>
<td>☐ How does light behave like a wave?</td>
<td>☐ The wave properties of light</td>
<td>☐ An Abridged “History” of Light &amp; Reflection, Refraction, Dispersion of Light</td>
</tr>
<tr>
<td>☐ How do we identify the electromagnetic spectrum?</td>
<td>☐ The double slit and single slit experiments</td>
<td>☐ Diffraction and Interference of Light</td>
</tr>
<tr>
<td>☐ How does wave speed relate to frequency?</td>
<td>☐ How light changes speed and direction when entering a new medium</td>
<td>☐ Diffraction Grating Lab</td>
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<td>☐ Interference by Thin Films</td>
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<td>☐ Maxwell’s Equations &amp; Properties of Electromagnetic Waves</td>
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### AP Physics 2

**Unit 10: Quantum Physics and Atomic Models**

**Time Allotted (days of instruction):** 16 days

**New Jersey Student Learning Standards (NJSLS):**

- HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
- HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

**AP Physics 1 and 2 Standards:**

- Essential Knowledge 6.F.3: Photons are individual energy packets of electromagnetic waves, with $E_{\text{photon}} = hf$, where $h$ is Planck's constant and $f$ is the frequency of the associated light wave.
  - a. In the quantum model of electromagnetic radiation, the energy is emitted or absorbed in discrete energy packets called photons. Discrete spectral lines should be included as an example.
  - b. For the short-wavelength portion of the electromagnetic spectrum, the energy per photon can be observed by direct measurement when electron emissions from matter result from the absorption of radiant energy.
c. Evidence for discrete energy packets is provided by a frequency threshold for electron emission. Above the threshold, emission increases with the frequency and not the intensity of absorbed radiation. The photoelectric effect should be included as an example.

- **Learning Objective (6.F.3.1)** The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect.
- **Essential Knowledge 6.F.4:** The nature of light requires that different models of light are most appropriate at different scales.
  a. The particle-like properties of electromagnetic radiation are more readily observed when the energy transported during the time of the measurement is comparable to $E_{\text{photon}}$.
  b. The wavelike properties of electromagnetic radiation are more readily observed when the scale of the objects it interacts with is comparable to or larger than the wavelength of the radiation.

- **Learning Objective (6.F.4.1)** The student is able to select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter.
- **Essential Knowledge 6.G.1:** Under certain regimes of energy or distance, matter can be modeled as a classical particle.
- **Learning Objective (6.G.1.1)** 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.
- **Essential Knowledge 6.G.2:** Under certain regimes of energy or distance, matter can be modeled as a wave. The behavior in these regimes is described by quantum mechanics.
  a. A wave model of matter is quantified by the de Broglie wavelength that increases as the momentum of the particle decreases.
  b. The wave property of matter was experimentally confirmed by the diffraction of electrons in the experiments of Clinton Joseph Davisson, Lester Germer, and George Paget Thomson.

- **Learning Objective (6.G.2.1)** 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 deBroglie wavelength smaller than the separation between adjacent atoms in the crystal.
- **Learning Objective (6.G.2.2)** 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.)

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<tbody>
<tr>
<td>Who determined the charge on an electron, and what was the name of the experiment?</td>
<td>The Oil Drop Experiment</td>
<td>Electrons</td>
</tr>
<tr>
<td>What assumption did Max Planck make to solve the Blackbody radiation problem?</td>
<td>Rutherford’s Experiment</td>
<td>X-Rays and Radioactivity</td>
</tr>
<tr>
<td>What properties of the Photoelectric effect could not be explained by the wave theory of light?</td>
<td>The Cathode Ray Tube Experiment</td>
<td>Blackbody Radiation, Quantized Energy</td>
</tr>
<tr>
<td>How did Albert Einstein explain the Photoelectric effect? Who first postulated that light was made up of particles?</td>
<td>The Photoelectric Effect</td>
<td>The Photoelectric Effect</td>
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<td></td>
<td>The Bohr Model of the Atom</td>
<td>Photoelectric Effect Lab</td>
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<td>Atomic Models</td>
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<td>Waves and Particles</td>
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<td>Quantum Mechanics</td>
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</table>
- Describe the Thomson Plum Pudding model of the atom.
- What experiment was performed by Ernest Rutherford? How did it change the Thomson model?
- How did Neils Bohr resolve the problems with the Rutherford model?

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### Technology Standards
**Standard 8.1 – Computer and Information Literacy**
All students will use computer applications to gather and organize information and to solve problems.
New Jersey Student Learning Standards (NJSLS):

- HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

- HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

AP Physics 1 and 2 Standards:

- Essential Knowledge 3.G.3: The strong force is exerted at nuclear scales and dominates the interactions of nucleons.
- Learning Objective (3.G.3.1): The student is able to identify the strong force as the force that is responsible for holding the nucleus together.
- Essential Knowledge 4.C.4: Mass can be converted into energy and energy can be converted into mass.
  a. Mass and energy are interrelated by $E = mc^2$
  b. Significant amounts of energy can be released in nuclear processes.
- Learning Objective (4.C.4.1): The student is able to apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.
- Essential Knowledge 5.C.1: Electric charge is conserved in nuclear and elementary particle reactions, even when elementary particles are produced or destroyed. Examples should include equations representing nuclear decay.
- Learning Objective (5.C.1.1): 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.
- Essential Knowledge 5.G.1: The possible nuclear reactions are constrained by the law of conservation of nucleon number.
- Learning Objective (5.G.1.1): 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.
- Essential Knowledge 7.C.3: The spontaneous radioactive decay of an individual nucleus is described by probability.
  a. In radioactive decay processes, we cannot predict when any one nucleus will undergo a change; we can only predict what happens on the average to a large number of identical nuclei.
  b. In radioactive decay, mass and energy are interrelated, and energy is released in nuclear processes as kinetic energy of the products or as electromagnetic energy.
  c. The time for half of a given number of radioactive nuclei to decay is called the half-life.
  d. Different unstable elements and isotopes have vastly different half-lives, ranging from small fractions of a second to billions of years.

Learning Objective (7.C.3.1): 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.

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<td>What particles make up the nucleus? What is the general term for them? What are those particles composed of?</td>
<td>Mass defect and binding energy</td>
<td>Nuclear Structure, Isotopes, Atomic Mass</td>
</tr>
<tr>
<td>What is the definition of the atomic number? What is its symbol?</td>
<td>Alpha decay</td>
<td>Binding Energy and Mass Defect</td>
</tr>
<tr>
<td>What is the definition of the atomic mass number? What is its symbol?</td>
<td>Beta decay</td>
<td>Radioactivity and Half Life</td>
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<td>What is the definition of mass defect?</td>
<td>Gamma Radiation</td>
<td>Nuclear Reactions</td>
</tr>
<tr>
<td>What is the definition of binding energy?</td>
<td>Fission</td>
<td>Fission and Fusion</td>
</tr>
<tr>
<td>What is the spontaneous emission of radiation from nuclei called? What are the three types?</td>
<td>Fusion</td>
<td>Nuclear Physics Lab</td>
</tr>
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<td>What is nuclear fusion and where does it occur?</td>
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