TOWNSHIP OF UNION PUBLIC SCHOOLS

SC 530
AP Physics 2
Curriculum Guide
January 2019

Mission Statement

The mission of the Township of Union Public Schools is to build on the foundations of honesty, excellence, integrity, strong family, and community partnerships. We promote a supportive learning environment where all students are challenged, inspired, empowered, and respected as diverse learners. Through cultivation of students' intellectual curiosity, skills and knowledge, our students can achieve academically and socially as well as contribute as responsible and productive citizens of our global community.

Philosophy Statement

The Township of Union Public School District, as a societal agency, reflects democratic ideals and concepts through its educational practices. It is the belief of the Board of Education that a primary function of the Township of Union Public School System is the formulation of a learning climate conducive to the needs of all students in general, providing therein for individual differences. The school operates as a partner with the home and community.

Statement of District Goals

- Develop reading, writing, speaking, listening, and mathematical skills.
- Develop a pride in work and a feeling of self-worth, self-reliance, and self-discipline.
- Acquire and use the skills and habits involved in critical and constructive thinking.
- Develop a code of behavior based on moral and ethical principles.
- Work with others cooperatively.
- Acquire a knowledge and appreciation of the historical record of human achievement and failures and current societal issues.
- Acquire a knowledge and understanding of the physical and biological sciences.
- Participate effectively and efficiently in economic life and the development of skills to enter a specific field of work.
- Appreciate and understand literature, art, music, and other cultural activities.
- Develop an understanding of the historical and cultural heritage.
- Develop a concern for the proper use and/or preservation of natural resources.
- Develop basic skills in sports and other forms of recreation.

Course Description

Course Description AP Physics 2: Algebra-Based is the equivalent to a second-semester college course in algebra-based physics. The course covers fluid mechanics; thermodynamics; electricity and magnetism; optics; and atomic and nuclear physics

Course Proficiencies

Students will be able to…

1. Read, interpret and display graphical information.
2. Design experiments, execute them and interpret the results.
3. Use Kinematics equations to solve conceptual and quantitative problems in one and two dimensions.
4. Have a strong conceptual and mathematical knowledge of Newton’s Laws of motion.
5. Use their knowledge of the transformation of energy to interpret the world around them.
6. Use skills and equations to understand the fundamental forces that drive the universe.
7. Explain mathematically and conceptually the different types of waves and how waves propagate.
8. Demonstrate mathematically and conceptually the connection between linear and rotational motion.
9. Explain mathematically and conceptually problems relating to momentum.
10. Relate Newton’s law of gravitation to both celestial and terrestrial phenomena.
11. Explain mathematically and conceptually the concepts of Electricity, Charge and Resistance.

Recommended Text

Giancoli, D.C. Physics: Principles with Applications. Englewood Cliffs, NJ: Prentice Hall.

Units

Unit 1: Fluid Mechanics

Unit 2: Thermodynamics

Unit 3: Electrostatics

Unit 4: Electric Current

Unit 5: Magnetism

Unit 6: Waves and Optics

Unit 7: Modern Physics

Pacing Guide

Content	Weeks
Unit 1: Fluid Mechanics	3
Unit 2: Thermodynamics	3
Unit 3: Electrostatics	3
Unit 4: Electric Current	3
Unit 5: Magnetism	3
Unit 6: Waves and Optics	3
Unit 7: Modern Physics	3

Unit 1: Fluids

GIANCOLI (7e): Chapter 10 (10-2 through 10-5, 10-7 through 10-10)

- Density
- Static Fluids
- Fluids in Motion; Flow Rate, Continuity and Bernoulli's Principle

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. [SP 4.2, 6.4]

3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces.[SP 6.1]

5.B.10.1: The student is able to use Bernoulli's equation to make calculations related to a moving fluid. [SP 2.2]

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. [SP 2.2]

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. [SP 2.2]

5.B.10.4: The student is able to construct an explanation of Bernoulli's equation in terms of the conservation of energy. [SP 6.2]

5.F.1.1: 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]

Guiding Questions

What causes pressure to be exerted by a fluid, and why does liquid pressure vary with depth when gas pressure does not?
How is the buoyant force generated, and how can this force be mathematically modeled?
Why does the buoyant force not vary significantly with depth, even though liquid pressure does?
How can conservation of mass and conservation of energy be used to predict the behavior of moving liquids?

<table>
<tr><td colspan="2"></td></tr>
<tr><th>Learning Objective</th><th>Activities / Assessment</th></tr>
<tr><td>Use Bernoulli’s equation and the relationship between force and/or pressure to make calculations related to a moving fluid. [LO 5.B.10.2, SP 2.2]</td><td rowspan="7">Laboratory Investigations
Water Pressure and Depth
Using Buoyant Force to Determine Water Density
Bernoulli Principle and Energy
Pascal
Balloon Lab
Floating Raft Lab
Water Tower Lab
Questioning
Exit Slips
Homework/Classwork
PHET Simulations
Quizzes
Tests
AP Practice Questions</td></tr>
<tr><td>Predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. [LO 1.E.1.1, SP 4.2, SP 6.4]. [LO 1.E.1.2, SP 4.1, SP 6.4]</td></tr>
<tr><td>Select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects</td></tr>
<tr><td>Make claims about various contact forces between objects based on the microscopic cause of those forces. [LO 3.C.4.1, SP 6.1]</td></tr>
<tr><td>Explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [LO 3.C.4.2, SP 6.2</td></tr>
<tr><td>Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [LO 3.A.2.1, SP 1.1]</td></tr>
<tr><td>Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [LO 3.B.2.1, SP 1.1, SP 1.4, SP 2.2]</td></tr>
</table>

Unit 2: Thermodynamics

GIANCOLI (7e): Chapter 13 (13-1 through 13-3, 13-5 through 13-9); Chapter 14 (14-1 through 14-2, 14-6 through 14-8); Chapter 15 (15-1 through 15-2, 15-4 and 15-7 through 15-10 (qualitative))

- Thermal Equilibrium and the Zeroth Law of Thermodynamics
- The Gas Laws and Absolute Temperature
- The Ideal Gas Law
- Energy Transfer: Conduction, Convection and Radiation
- The First Law of Thermodynamics
- Thermodynamic Processes and PV Diagrams
- The Second Law of Thermodynamics (qualitative)
- Entropy (qualitative)

1.E.3.1: The student is able to design an experiment and analyze data from it to examine thermal conductivity. [SP 4.1, 4.2, 5.1]

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. [SP 6.4]

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [SP 6.4, 7.2]

5.B.4.1: The student is able to describe and make predictions about the internal energy of systems. [SP 6.4, 7.2]

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. [SP 1.4, 2.1, 2.2]

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). [SP 6.4, 7.2]

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. [SP 2.2, 6.4]

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. [SP 4.2, 5.1]

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. [SP 1.2]

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. [SP 6.4, 7.2]

5.B.7.2: The student is able to create a plot of pressure versus volume for a thermodynamic process from given data. [SP 1.1]

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). [SP 1.1, 1.4, 2.2]

7.A.1.1: The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. [SP 6.4, 7.2]

7.A.1.2: Treating a gas molecule as an object (i.e., ignoring its internal structure), 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]

7.A.2.1: The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system. [SP 7.1]

7.A.2.2: 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]

7.A.3.1: 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]

7.A.3.2: 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]

7.A.3.3: 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] 7.B.1.1: 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] 7.B.2.1: 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]
Guiding Questions How are heat and temperature explained on a molecular level? How do gas molecules exert pressure on the walls of a container? How is the expansion of a gas related to mechanical work? What is entropy, and how is it related to the irreversibility of most real-world processes?

Learning Objective	**Activities / Assessment**
Make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed. [LO 5.D.1.6, SP 6.4]	**Laboratory Investigations** Calculating Thermal Conductivity Heat Engine Hair Dryer Efficiency Phase Change Lab Thermal Expansion Lab Entropy Dice Activity Questioning Exit Slips Homework/Classwork PHET Simulations Quizzes Tests AP Practice Questions
Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values. [LO 5.D.1.7, SP 2.1, SP 2.2]	
Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. [LO 5.D.2.5, SP 2.1, SP 2.2]	
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. [LO 7.A.3.2, SP 3.2, SP	

4.2]	
\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. [LO 7.A.3.3, SP 5.1]	
Treating a gas molecule as an object, analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables. [LO 7.A.1.2, SP 1.4, SP 2.2]	
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. [LO 7.A.3.1, SP 6.4, SP 7.2]	
Make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. [LO 7.A.1.1, SP 6.4, SP 7.2]	
Apply F m= g to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. [LO 2.B.1.1, SP 2.2, SP 7.2]	
Model verbally or visually the properties of a system based on its substructure and to relate this to changes in the system properties over time as external variables are changed. [LO 1.A.5.1, SP 1.1, SP 7.1]	

Unit 3: Electrostatics

GIANCOLI (7e): Chapter 16 (16-1 through 16-9) and Chapter 17 (17-1 through 17-6)

- Static Electricity; Electric Charge and its Conservation
- Insulators and Conductors
- Charging Processes: Friction, Conduction and Induction
- Coulomb's Law
- Electric Field
- Electric Potential and Potential Difference
- Relation Between Electric Potential and Electric Field
- Equipotential Lines
- Electric Potential due to Point Charges

1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge. [SP 6.4]

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. [SP 6.4, 7.2]

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. [SP 6.4, 7.2]

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. [SP6.1]

1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated. [SP 1.5, 6.1, 7.2]

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.[SP 6.4, 7.2]

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.[SP 2.2]

2.C.2.1: 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]

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. [SP 6.2]

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. [SP 2.2, 6.4, 7.2]

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. [SP 1.4, 2.2]

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. [SP 1.1, 2.2]

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. [SP 2.2]

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. [SP 1.1, 2.2, 7.1]

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. [SP 1.4, 6.4, 7.2]

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. [SP 6.4, 7.2]

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. [SP 6.4, 7.2]

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. [SP 1.4]

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. [SP 2.2]

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. [SP 1.4, 6.4]

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [SP 1.1]

3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself. [SP 6.1]

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force. [SP 1.4]

3.A.3.4: The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge. [SP6.1, 6.4]

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [SP1.4, 6.2]

3.A.4.2: The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [SP6.4, 7.2]

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [SP1.4]

3.B.1.3: The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [SP1.5, 2.2]

3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [SP6.4, 7.2]

3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [SP1.1, 1.4, 2.2]

LO 3.C.2.1: The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. [SP 2.2, 6.4]

3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [SP7.2]

3.C.2.3: The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2 to 4 point charges, though more are permitted in situations of high symmetry). [SP 2.2]

3.G.1.2: The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces. [SP7.1]

LO 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. [SP 7.1]

4.E.3.1: The student is able to make predictions about the redistribution of charge during charging by friction, conduction, and induction. [SP6.4]

4.E.3.2: The student is able to make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects. [SP6.4, 7.2]

4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors. [SP1.1, 1.4, 6.4]

4.E.3.4: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction. [SP1.1, 1.4, 6.4]

4.E.3.5: 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. [SP3.2, 4.1, 4.2, 5.1, 5.3]

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [SP 6.4, 7.2]

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. [SP 1.4, 2.1]

5.C.2.1: The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system. [SP6.4]

5.C.2.2: The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data. [SP4.2, 5.1]

5.C.2.3: The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects. [SP 4.1]

Guiding Questions

What happens at the atomic level when an object is charged or polarized?
What is an electric field, and how can it be used to calculate force?
What is an electric potential, and how is it related to potential energy?
How can we visualize the electric field and electric potential produced by a charge configuration?

<table>
<tr><th>Learning Objective</th><th>Activities / Assessment</th></tr>
<tr><td>Predict electric charges on objects within a system by application of the principle of charge conservation within a system. [LO 5.C.2.1, SP 6.4]</td><td rowspan="5">Laboratory Investigations
Balloons and Static Charge
Electroscope Polarization
Estimated Electrons on Charged Beads
Mapping the Electric Field Around a Dipole
Mapping the Electric Field Between Parallel Plates
Questioning
Exit Slips
Homework/Classwork
PHET Simulations
Quizzes</td></tr>
<tr><td>Make predictions about the redistribution of charge during charging by friction, conduction, and induction. [LO 4.E.3.1, SP 6.4]</td></tr>
<tr><td>Make claims about natural phenomena based on conservation of electric charge. [LO 1.B.1.1, SP 6.4]</td></tr>
<tr><td>Construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. [LO 1.B.2.1, SP 6.2]</td></tr>
<tr><td>Design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze</td></tr>
</table>

that data. [LO 5.C.2.2, SP 4.2, SP 5.1]	Tests AP Practice Questions
Make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. [LO 1.B.2.2, SP 6.4, SP 7.2]	
Challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object. [LO 1.B.2.3, SP 6.1]	
Construct a representation of the distribution of fixed and mobile charge in insulators and conductors. [LO 4.E.3.3, SP 1.1, SP 1.4, SP 6.4]	
Qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field. [LO 2.C.2.1, SP 2.2, SP 6.4]	
Explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object. [LO 2.C.3.1, SP 6.2]	

Unit 4: Electric Circuit

GIANCOLI (7e): Chapter 17 (17-7); Chapter 18 (18-1 through 18-5); Chapter 19 (19-1 through 19-6)

- Electric Current
- Ohm's Law: Resistance and Resistors
- Resistivity
- Capacitance
- Storage of Electric Energy
- Electric Power
- Resistors in Series and Parallel
- Kirchhoff's Rules
- RC Circuits (steady state only)

1.E.2.1: The student is able to choose and justify the selection of data needed to determine resistivity for a given material. [SP

4.1]

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. [SP2.2, 6.4]

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. [SP4.1, 4.2]

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. [SP5.1]

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. [SP2.2, 6.4]

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. [SP6.1, 6.4]

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. [SP 2.2, 4.2, 5.1]

5.B.9.4: The student is able to analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff's loop rule.[SP5.1]

5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. [SP6.4]

5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. [SP2.1, 2.2]

5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff's Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. [SP4.1, 4.2, 5.1, 5.3]
5.B.9.8: The student is able to translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor. [SP1.5]
5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation. [SP6.4, 7.2]
5.C.3.5: The student is able to determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. [SP1.4, 2.2]
5.C.3.6: The student is able to determine missing values and direction of electric current in branches of a circuit with both 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. [SP1.4, 2.2]
5.C.3.7: 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]

Guiding Questions

What factors affect the resistance of a material?
How do charge conservation and energy conservation apply to direct current circuits?
What is common to elements in series and parallel circuits?
How do capacitors affect current in a circuit immediately after a switch is closed, as well as under steady-state conditions?

Learning Objective	**Activities / Assessment**
Choose and justify the selection of data needed to determine resistivity for a given material. [LO 1.E.2.1, SP 4.1]	**Laboratory Investigations** Resistivity of Conductive Paper Kirchhoff's Rules (Multiple Investigations) Bulb Brightness in Parallel and Series Circuits Ohm's Law Questioning Exit Slips Homework/Classwork PHET Simulations
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. [LO 4.E.4.2, SP 4.1, SP 4.2]	
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. [LO 1.B.1.2, SP 6.4, SP 7.2]	

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. [LO 4.E.4.3, SP 5.1]	Quizzes Tests AP Practice Questions
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. [LO 4.E.4.1, SP 2.2, SP 6.4]	
Translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor. [LO 5.B.9.8, SP 1.5]	
Determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. [LO 5.C.3.5, SP 1.4, SP 2.2]	
Analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff's loop rule $\sum \Delta V = 0$. [LO 5.B.9.4, SP 5.1]	
Refine and analyze a scientific question for an experiment using Kirchhoff's loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. [LO 5.B.9.7, SP 4.1, SP 4.2, SP 5.1, SP 5.3]	
Mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. [LO 5.B.9.6, SP 2.1, SP 2.2]	

Unit 5: Magnetism

GIANCOLI (7e): Chapter 20 (20-1 through 20-6 and 20-10 through 20-12(hysteresis is not required);Chapter 21 (21-1 through 21-4)

- Magnets and Magnetic Fields
- Force on an Electric Current in a Magnetic Field
- Force on an Electric Charge Moving in a Magnetic Field

- Induced EMF
- Faraday's Law of Induction; Lenz's Law
- EMF Induced in a Moving Conductor

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. [SP 2.2, 6.4, 7.2]

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. [SP 2.2]

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. [SP 1.1]

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. [SP 1.2]

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. [SP 1.4]

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [SP 1.1]

3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself. [SP 6.1]

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force. [SP1.4]

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [SP1.4, 6.2]

3.A.4.2: The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [SP6.4, 7.2]

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [SP1.4]

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. [SP1.4] 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. [SP4.2, 5.1] 4.E.1.1: 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] 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. [SP 6.4]
Guiding Questions How can we describe a magnetic field due to single or multiple sources? How does a magnetic field interact with electric charge? How can we combine a magnetic field with an electric field to produce a beam of charged particles with a single velocity? How can changing magnetic flux produce an electric potential?

Learning Objective	**Activities / Assessment**
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. [LO 2.D.3.1, SP 1.2]	**Laboratory Investigations** Mapping a Magnetic Field with Iron Filings Mapping a Magnetic Field with Compasses Compound Magnets Magnetic Force and Current Evidence of Electromagnetic Induction Questioning Exit Slips Homework/Classwork PHET Simulations
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 semi-quantitative 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. [LO 2.C.4.1, SP	

2.2, SP 6.4, SP 7.2]	Quizzes Tests AP Practice Questions
Create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires. [LO 2.D.2.1, SP 1.1]	
Apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. [LO 2.D.1.1, SP 2.2]	
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. [LO 3.C.3.1, SP 1.4]	
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. [LO 3.C.3.2, SP 4.2, SP 5.1]	
Reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [LO 3.B.1.3, SP 1.5, SP 2.2]	
Predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [LO 3.B.1.4, SP 6.4, SP 7.2]	
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. [LO 4.E.2.1, SP 6.4]	

Unit 6: Waves and Optics

GIANCOLI (7e): Chapter 11 (11-7 through 11-9);Chapter 17 (17-7); Chapter 22 (22-2 through 22-3, 22-5 through 22-6); Chapter 23 (23-1 through 23-8); Chapter 24 (24-1, 24-3, 24-5 through 24-6 and 24-8)

- Electromagnetic Waves
- Polarization, Reflection and Refraction
- Formation of Images by Spherical Mirrors
- Formation of Images by Thin Lenses
- Interference - Young's Double Slit Experiment
- Diffraction
- Interference by Thin Films

6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [SP1.2]
6.A.1.3: The student is able to 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. [SP5.1, 6.2]
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. [SP 6.4, 7.2]
6.B.3.1: The student is able to 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, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa. [SP 1.5]
6.C.1.1: The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. [SP6.4, 7.2]
6.C.1.2: The student is able to construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition. [SP1.4]
6.C.2.1: The student is able to 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. [SP 1.4, 6.4, 7.2]
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. [SP 1.4, 6.4]

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. [SP 6.4, 7.2] 6.E.1.1: The student is able to 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 reflected, and some is absorbed. [SP 6.4, 7.2] 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.[SP 6.4, 7.2] 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. [SP1.1, 1.4] 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). [SP4.1, 5.1, 5.2, 5.3] 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. [SP6.4, 7.2] LO 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. [SP 3.2, 4.1, 5.1, 5.2, 5.3] LO 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. [SP 1.4, 2.2] LO 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. [SSP 1.4, 2.2] LO 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. [SP 3.2, 4.1, 5.1, 5.2, 5.3] 6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation. [SP 6.4, 7.2]
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.[SP 1.1]
Guiding Questions How do mechanical waves and electromagnetic waves propagate? What causes light to bend as it exits one medium and enters another? How can we use the thin lens (or mirror) equation to predict the size and location of an image? How do the principal rays commonly used in ray diagrams obey the law of reflection for mirrors and the law of refraction for lenses?

Learning Objective	Activities / Assessment
Describe representations of transverse and longitudinal waves. [LO 6.A.1.2, SP 1.2]	**Laboratory Investigations** Diffraction Laser Lab Polarizing Filters Law of Reflection Determining the Index of Refraction Spherical Mirror Lenses Questioning Exit Slips Homework/Classwork PHET Simulations Quizzes Tests AP Practice Questions
Use a visual representation of a periodic mechanical wave to determine wavelength of the wave. [LO 6.B.2.1, SP 1.4]	
Describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present. [LO 6.F.2.1, SP 1.1]	
Make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. [LO 6.C.1.1, SP 6.4, SP 7.2]	
Construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition. [LO 6.C.1.2, SP 1.4]	
Make claims about the diffraction pattern produced when a wave passes through a small opening, and 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. [LO 6.C.2.1, SP 1.4, SP 6.4, SP 7.2]	
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. [LO 6.C.4.1, SP 6.4, SP 7.2]	
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, but larger than the wavelength. [LO 6.C.3.1, SP 1.4, SP 6.4]	
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. [LO 6.E.3.1, SP 1.1, SP 1.4]	

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. [LO 6.E.3.3, SP 6.4, SP 7.2]	
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. [LO 6.E.4.1, SP 3.2, SP 4.1, SP 5.1, SP 5.2, SP 5.3]	
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. [LO 6.E.4.2, SP 1.4, SP 2.2]	

Unit 7: Modern Physics

GIANCOLI (7e): Chapter 26 (26-2 and 26-9); Chapter 27 (27-1 through 27-8); Chapter 27 (27-10 through 27-13 and 27-6); Chapter 28 (28-1 through 28-5); Chapter 30 (30-1 through 30-8); Chapter 31 (31-1 through 31-3)

- Reasons that Classical Mechanics must be replaced by Special Relativity (see 1.3.D.1)
- Planck's Quantum Hypothesis
- Photon Theory of Light and the Photoelectric Effect
- Wave Nature of Matter
- Atomic Energy Levels: Emission and Absorption Spectra
- Nuclear Reactions and Decays: fission, fusion, alpha decay, beta decay, or gamma decay.
- Conservation Laws: Charge, Nucleon and Mass-Energy

1.A.2.1: The student is able to 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. [SP 1.1,7.1]

1.A.4.1: The student is able to 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. [SP 1.1, 7.1]

1.C.4.1: The student is able to articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass-energy. [SP 6.3]

1.D.1.1: The student is able to 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. [SP 6.3]

1.D.3.1: The student is able to 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. [Students will be expected to recognize situations in which nonrelativistic classical physics breaks down and to explain how relativity addresses that breakdown, but students will not be expected to know in which of two reference frames a given series of events corresponds to a greater or lesser time interval, or a greater or lesser spatial distance; they will just need to know that observers in the two reference frames can “disagree” about some time and distance intervals.] [SP 6.3, 7.1]

3.G.3.1: The student is able to identify the strong force as the force that is responsible for holding the nucleus together. [SP 7.2]

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. [SP 2.2, 2.3, 7.2]

5.B.8.1: The student is able to 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 characterization of the frequency of radiation emitted or absorbed. [SP 1.2, 7.2]

5.B.11.1: 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]

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. [SP 6.4, 7.2]

5.D.1.6: The student is able to make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed. [SP 6.4]

5.D.1.7: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values. [SP2.1, 2.2]

5.D.2.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. [SP 2.1, 2.2]

5.D.2.6: The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. [SP6.4, 7.2]

5.D.3.2: The student is able to make predictions about the velocity of the center of mass for interactions within a defined one-dimensional system. [SP6.4]

5.D.3.3: The student is able to make predictions about the velocity of the center of mass for interactions within a defined two-dimensional system. [SP6.4]

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. [SP 6.4]

6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect.[SP 6.4]

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.[SP 6.4, 7.1]

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. [SP 6.4, 7.1]

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 de Broglie wavelength smaller than the separation between adjacent atoms in the crystal. [SP6.1]

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.) [SP6.4]

7.C.1.1: 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]

7.C.2.1: 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]

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. [SP 6.4]

7.C.4.1: The student is able to construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. [For questions addressing stimulated emission, students will not be expected to recall the details of the process, such as the fact that the emitted photons have the same frequency and phase as the incident photon; but given a representation of the process, students are expected to make inferences such as figuring out from energy conservation that since the atom loses energy in the process, the emitted photons taken together must carry more energy than the incident photon.] [SP 1.1, 1.2]

Guiding Questions

What is the photoelectric effect?
Under what conditions does a particle act like a wave or a wave act like a particle?
What are the major implications of the theory of relativity?
What quantities are conserved in a nuclear reaction?

Learning Objective	Activities / Assessment
Construct representations of the differences between a fundamental particle and a system composed of fundamental particles and relate this to the properties and scales of the systems being investigated. [LO 1.A.2.1, SP 1.1, SP 7.1]	**Laboratory Investigations** Determination of Planck's Constant Photoelectric Effect (Simulation Lab) Electron Diffraction (Simulation Lab) Nuclear Decay (Simulation Lab) Nuclear Fission (Simulation Lab) Questioning
Challenge the claim that an electric charge smaller than the elementary charge has been isolated. [LO 1.B.3.1, SP 1.5, SP 6.1, SP 7.2]	
Construct representations of how the properties of a system are	

determined by the interactions of its constituent substructures. [LO 1.A.5.2, SP 1.1, SP 1.4, SP 7.1]	Exit Slips Homework/Classwork PHET Simulations Quizzes Tests AP Practice Questions
Use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region. [LO 7.C.1.1, SP 1.4]	
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. [LO 7.C.2.1, SP 1.4]	
Construct representations of the energy-level structure of an electron in an atom and relate this to the properties and scales of the systems being investigated. [LO 1.A.4.1, SP 1.1, SP 7.1]	
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 characterization of the frequency of radiation emitted or absorbed. [LO 5.B.8.1, SP 1.2, SP 7.2]	
Select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter. [LO 6.F.4.1, SP 6.4, SP 7.1]	
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. [LO 6.G.2.1, SP 6.1]	

The following standards are threaded throughout all units of the NJSLS-Science:

21st Century Life and Career Standards: Career Awareness, ELD Standards, and Technology Standards.

WIDA ELD Standards: Teaching with Standards | WIDA

WIDA has established language development standards for English and Spanish. These standards represent the language students need to be successful in early childhood programs and Grades K-12.

The first standard, **Social and Instructional Language,** reflects the ways in which students interact socially to build community and establish working relationships with peers and teachers in ways that support learning.

The remaining four standards present ways multilingual learners can communicate information, ideas and concepts necessary for academic success in **Language Arts, Math, Science** and **Social Studies**.

Specifically in Science Standard 4- Language of Science- English Language learners communicate information, ideas and concepts necessary for academic success in the content area of science.

New Jersey Student Learning Standards

Standard 9

21st Century Life and Careers

In today's global economy, students need to be lifelong learners who have the knowledge and skills to adapt to an evolving workplace and world. To address these demands, Standard 9, 21st Century Life and Careers, which includes the 12 Career Ready Practices, establishes clear guidelines for what students need to know and be able to do in order to be successful in their future careers and to achieve financial independence.

Mission: *21st century life and career skills enable students to make informed decisions that prepare them to engage as active citizens in a dynamic global society and to successfully meet the challenges and opportunities of the 21st century global workplace.*

Vision: To integrate 21st Century life and career skills across the K-12 curriculum and to foster a population that:

- Continually self-reflects and seeks to improve the essential life and career practices that lead to success.
- Uses effective communication and collaboration skills and resources to interact with a global society.
- Is financially literate and financially responsible at home and in the broader community.
- Is knowledgeable about careers and can plan, execute, and alter career goals in response to changing societal and economic conditions.
- Seeks to attain skill and content mastery to achieve success in a chosen career path.

Career Ready Practices

Career Ready Practices describe the career-ready skills that all educators in all content areas should seek to develop in their students. They are practices that have been linked to increase college, career, and life success. Career Ready Practices should be taught and reinforced in all career exploration and preparation programs with increasingly higher levels of complexity and expectation as a student advances through a program of study.

CRP1. Act as a responsible and contributing citizen and employee.

Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.

CRP2. Apply appropriate academic and technical skills.

Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.

CRP3. Attend to personal health and financial well-being.

Career-ready individuals understand the relationship between personal health, workplace performance and personal well-being; they act on that understanding to regularly practice healthy diet, exercise and mental health activities. Career-ready individuals also take regular action to contribute to their personal financial wellbeing, understanding that personal financial security provides the peace of mind required to contribute more fully to their own career success.

CRP4. Communicate clearly and effectively and with reason.

Career-ready individuals communicate thoughts, ideas, and action plans with clarity, whether using written, verbal, and/or visual methods. They communicate in the workplace with clarity and purpose to make maximum use of their own and others' time. They are excellent writers; they master conventions, word choice, and organization, and use effective tone and presentation skills to articulate ideas. They are skilled at interacting with others; they are active listeners and speak clearly and with purpose. Career-ready individuals think about the audience for their communication and prepare accordingly to ensure the desired outcome.

CRP5. Consider the environmental, social and economic impacts of decisions.

Career-ready individuals understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.

CRP6. Demonstrate creativity and innovation.

Career-ready individuals regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.

CRP7. Employ valid and reliable research strategies.

Career-ready individuals are discerning in accepting and using new information to make decisions, changes. They use reliable research process to search for new information. They evaluate the validity of sources when considering the use and adoption of external information or practices in their workplace situation.

CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.

Career-ready individuals readily recognize problems in the workplace, understand the nature of the problem, and devise effective plans to solve the problem. They are aware of problems when they occur and take action quickly to address the problem; they thoughtfully investigate the root cause of the problem prior to introducing solutions. They carefully consider the options to solve the problem. Once a solution is agreed upon, they follow through to ensure the problem is solved, whether through their own actions or the actions of others.

CRP9. Model integrity, ethical leadership and effective management.

Career-ready individuals consistently act in ways that align personal and community-held ideals and principles while employing strategies to positively influence others in the workplace. They have a clear understanding of integrity and act on this understanding in every decision. They use a variety of means to positively impact the directions and actions of a team or organization, and they apply insights into human behavior to change others' action, attitudes and/or beliefs. They recognize the near-term and long-term effects that management's actions and attitudes can have on productivity, morals and organizational culture.

CRP10. Plan education and career paths aligned to personal goals.

Career-ready individuals take personal ownership of their own education and career goals, and they regularly act on a plan to attain these goals. They understand their own career interests, preferences, goals, and requirements. They have perspective regarding the pathways available to them and the time, effort, experience and other requirements to pursue each, including a path of entrepreneurship. They recognize the value of each step in the education and experiential process, and they recognize that nearly all career paths require ongoing education and experience. They seek counselors, mentors, and other experts to assist in the planning and execution of career and personal goals.

CRP11. Use technology to enhance productivity.

Career-ready individuals find and maximize the productive value of existing and new technology to accomplish workplace tasks and solve workplace problems. They are flexible and adaptive in acquiring new technology. They are proficient with ubiquitous technology applications. They understand the inherent risks-personal and organizational-of technology applications, and they take actions to prevent or mitigate these risks.

CRP12. Work productively in teams while using cultural global competence.

Career-ready individuals positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.

2014 New Jersey Core Curriculum Content Standards - Technology

Content Area	**Technology**		
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**		
Strand	**A. Technology Operations and Concepts:** *Students demonstrate a sound understanding of technology concepts, systems and operations.*		
Grade Level bands	**Content Statement Students will:**	**Indicator**	**Indicator**
P	Understand and use technology systems.	8.1.P.A.1	Use an input device to select an item and navigate the screen
		8.1.P.A.2	Navigate the basic functions of a browser.
	Select and use applications effectively and productively.	8.1.P.A.3	Use digital devices to create stories with pictures, numbers, letters and words.
		8.1.P.A.4	Use basic technology terms in the proper context in conversation with peers and teachers (e.g., camera, tablet, Internet, mouse, keyboard, and printer).
		8.1.P.A.5	Demonstrate the ability to access and use resources on a computing device.
K-2	Understand and use technology systems.	8.1.2.A.1	Identify the basic features of a digital device and explain its purpose.
	Select and use applications effectively and productively.	8.1.2.A.2	Create a document using a word processing application.
		8.1.2.A.3	Compare the common uses of at least two different digital applications and identify the advantages and disadvantages of using each.
		8.1.2.A.4	Demonstrate developmentally appropriate navigation skills in virtual environments (i.e. games, museums).
		8.1.2.A.5	Enter information into a spreadsheet and sort the information.
		8.1.2.A.6	Identify the structure and components of a database.
		8.1.2.A.7	Enter information into a database or spreadsheet and filter the information.
3-5	Understand and use technology systems.	8.1.5.A.1	Select and use the appropriate digital tools and resources to accomplish a variety of tasks including solving problems.
	Select and use applications effectively	8.1.5.A.2	Format a document using a word processing application to enhance text

	and productively.		and include graphics, symbols and/ or pictures.
		8.1.5.A.3	Use a graphic organizer to organize information about problem or issue.
		8.1.5.A.4	Graph data using a spreadsheet, analyze and produce a report that explains the analysis of the data.
		8.1.5.A.5	Create and use a database to answer basic questions.
		8.1.5.A.6	Export data from a database into a spreadsheet; analyze and produce a report that explains the analysis of the data.
6-8	Understand and use technology systems.	8.1.8.A.1	Demonstrate knowledge of a real world problem using digital tools.
	Select and use applications effectively and productively.	8.1.8.A.2	Create a document (e.g. newsletter, reports, personalized learning plan, business letters or flyers) using one or more digital applications to be critiqued by professionals for usability.
		8.1.8.A.3	Use and/or develop a simulation that provides an environment to solve a real world problem or theory.
		8.1.8.A.4	Graph and calculate data within a spreadsheet and present a summary of the results
		8.1.8.A.5	Create a database query, sort and create a report and describe the process, and explain the report results.
9-12	Understand and use technology systems.	8.1.12.A.1	Create a personal digital portfolio which reflects personal and academic interests, achievements, and career aspirations by using a variety of digital tools and resources.
	Select and use applications effectively and productively.	8.1.12.A.2	Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.
		8.1.12.A.3	Collaborate in online courses, learning communities, social networks or virtual worlds to discuss a resolution to a problem or issue.
		8.1.12.A.4	Construct a spreadsheet workbook with multiple worksheets, rename tabs to reflect the data on the worksheet, and use mathematical or logical functions, charts and data from all worksheets to convey the results.
		8.1.12.A.5	Create a report from a relational database consisting of at least two tables and describe the process, and explain the report results.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**B. Creativity and Innovation:** *Students demonstrate creative thinking, construct knowledge and develop innovative products and process using technology.*

Grade Level bands	Content Statement Students will:	Indicator	Indicator
P	Apply existing knowledge to generate new ideas, products, or processes. Create original works as a means of personal or group expression.	8.1.P.B.1	Create a story about a picture taken by the student on a digital camera or mobile device.
K-2		8.1.2.B.1	Illustrate and communicate original ideas and stories using multiple digital tools and resources.
3-5		8.1.5.B.1	Collaborative to produce a digital story about a significant local event or issue based on first-person interviews.
6-8		8.1.8.B.1	Synthesize and publish information about a local or global issue or event (ex. telecollaborative project, blog, school web).
9-12		8.1.12.B.2	Apply previous content knowledge by creating and piloting a digital learning game or tutorial.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**C. Communication and Collaboration:** *Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.*

Grade Level bands	**Content Statement**	**Indicator**	**Indicator**
P	Interact, collaborate, and publish with peers, experts, or others by employing a variety of digital environments and media. Communicate information and ideas to multiple audiences using a variety of media and formats. Develop cultural understanding and global awareness by engaging with learners of other cultures. Contribute to project teams to produce original works or solve problems.	8.1.P.C.1	Collaborate with peers by participating in interactive digital games or activities.
K-2		8.1.2.C.1	Engage in a variety of developmentally appropriate learning activities with students in other classes, schools, or countries using various media formats such as online collaborative tools, and social media.
3-5		8.1.5.C.1	Engage in online discussions with learners of other cultures to investigate a worldwide issue from multiple perspectives and sources, evaluate findings and present possible solutions, using digital tools and online resources for all steps.
6-8		8.1.8.C.1	Collaborate to develop and publish work that provides perspectives on a global problem for discussions with learners from other countries.
9-12		8.1.12.C.1	Develop an innovative solution to a real world problem or issue in collaboration with peers and experts, and present ideas for feedback through social media or in an online community.

Content Area	**Technology**		
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**		
Strand	**D. Digital Citizenship:** *Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.*		
Grade Level bands	**Content Statement**	**Indicator**	**Indicator**
K-2	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.2.D.1	Develop an understanding of ownership of print and nonprint information.
3-5	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.5.D.1	Understand the need for and use of copyrights.
		8.1.5.D.2	Analyze the resource citations in online materials for proper use.
	Demonstrate personal responsibility for lifelong learning.	8.1.5.D.3	Demonstrate an understanding of the need to practice cyber safety, cyber security, and cyber ethics when using technologies and social media.
	Exhibit leadership for digital citizenship.	8.1.5.D.4	Understand digital citizenship and demonstrate an understanding of the personal consequences of inappropriate use of technology and social media.
6-8	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.8.D.1	Understand and model appropriate online behaviors related to cyber safety, cyber bullying, cyber security, and cyber ethics including appropriate use of social media.
	Demonstrate personal responsibility for lifelong learning.	8.1.8.D.2	Demonstrate the application of appropriate citations to digital content.
		8.1.8.D.3	Demonstrate an understanding of fair use and Creative Commons to intellectual property.
	Exhibit leadership for digital citizenship.	8.1.8.D.4	Assess the credibility and accuracy of digital content.
		8.1.8.D.5	Understand appropriate uses for social media and the negative consequences of misuse.
9-12	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.12.D.1	Demonstrate appropriate application of copyright, fair use and/or Creative Commons to an original work.
	Demonstrate personal responsibility for	8.1.12.D.2	Evaluate consequences of unauthorized electronic access (e.g., hacking)

	lifelong learning.		and disclosure, and on dissemination of personal information.
		8.1.12.D.3	Compare and contrast policies on filtering and censorship both locally and globally.
	Exhibit leadership for digital citizenship.	8.1.12.D.4	Research and understand the positive and negative impact of one's digital footprint.
		8.1.12.D.5	Analyze the capabilities and limitations of current and emerging technology resources and assess their potential to address personal, social, lifelong learning, and career needs.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**E: Research and Information Fluency:** *Students apply digital tools to gather, evaluate, and use information.*

Grade Level bands	**Content Statement** **Students will:**	**Indicator**	**Indicator**
P	Plan strategies to guide inquiry.	8.1.P.E.1	Use the Internet to explore and investigate questions with a teacher's support.
K-2	Plan strategies to guide inquiry Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.	8.1.2.E.1	Use digital tools and online resources to explore a problem or issue.
3-5	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.	8.1.5.E.1	Use digital tools to research and evaluate the accuracy of, relevance to, and appropriateness of using print and non-print electronic information sources to complete a variety of tasks.

6-8	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks. Process data and report results.	8.1.8.E.1	Effectively use a variety of search tools and filters in professional public databases to find information to solve a real world problem.
9-12	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks. Process data and report results.	8.1.12.E.1	Produce a position statement about a real world problem by developing a systematic plan of investigation with peers and experts synthesizing information from multiple sources.
		8.1.12.E.2	Research and evaluate the impact on society of the unethical use of digital tools and present your research to peers.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**F: Critical thinking, problem solving, and decision making:** *Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.*

Grade Level bands	**Content Statement Students will:**	**Indicator**	**Indicator**
K-2	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project.	8.1.2.F.1	Use geographic mapping tools to plan and solve problems.

	Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.		
3-5	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions	8.1.5.F.1	Apply digital tools to collect, organize, and analyze data that support a scientific finding.
6-8	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.	8.1.8.F.1	Explore a local issue, by using digital tools to collect and analyze data to identify a solution and make an informed decision.
9-12	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project.	8.1.12.F.1	Evaluate the strengths and limitations of emerging technologies and their impact on educational, career, personal and or social needs.

	Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.		