# MANCHESTER REGIONAL HIGH SCHOOL

## Honors Physics

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Curriculum Committee

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# College Prep Physics: Algebra Based and Honors Physics

## I. Course Description

This course represents the first year in a comprehensive two year sequence of Algebra/Trigonometry based physics. This first course is comprised of Mechanics, which is studied for the first 40% of the year; Electricity and Magnetism, which is studied for the next 40%; and, finally, Simple Harmonic Motion, Waves, Light and the Bohr model of the Hydrogen atom for the last 20%.

The order of the topics has been geared to use and reinforce the mathematics that the students are studying. For this reason, this first year course is geared towards reinforcing skills in algebra and requires no trigonometry. This is accomplished by restricting the first year course to problems that can be simplified to one-dimensional form. While vectors are introduced, they are only added and subtracted in one dimension at a time. This allows students to do about 90% of the Physics AP B topics. Connections are also developed between the analysis of motion and graphical analysis, collision problems and the solving of systems of equations, etc.

The second year course, AP Physics B, begins with a brief review of that same material while introducing multi-dimensional problems, through the addition and subtraction of vectors in two and three dimensions. This is coordinated with the student's study of trigonometry.

Throughout both years, students will be involved in problem-solving activities on an individual, small group and large group basis. Through this process the ability to read and understand problems, break them down into their component parts and then create and present solutions will be developed.

Students who have successfully completed this course may elect to move onto Physics AP B.

# II. Course Outline

**1. One- Dimensional Kinematics**

a. Motion in one dimension
b. Vectors vs. scalars
c. Displacement vs. Distance
d. Velocity vs. Speed
e. Using the four kinematics equations to solve problems:
    a. $x = xo + v_o t + \frac{1}{2} at^2$
    b. $v = v^o + at$
    c. $v^2 = v_o^2 + 2a\Delta x$
    d. $v_{avg} = (v + v_o)/2$
f. Graphical interpretation of motion

**2. Dynamics**

a. Aristotelian World View
b. Galilean view
c. Newton's Laws
d. Free body Diagrams
e. Gravity near the earth's surface and "g"
f. Mass versus weight ($W = mg$)
g. Use $\Sigma F = ma$ and free body diagrams to solve problems in one dimension
h. Surface Forces: Normal Force and Friction
i. Apparent weight
j. Static and Kinetic Friction

**3. Circular Motion**

a. Net force required for circular motion ($a = mv^2/r$)
b. Application of Free Body diagrams and Newton's Laws to circular motion problems
c. Universal gravitation
d. Solve problems with universal gravitation ($F = GMm/r^2$)
e. Satellites and 'weightless"
f. Kepler's Laws and Newton's Synthesis

**4. Linear Momentum**

a. Momentum ($p = mv$)
b. Impulse ($I = F\Delta t = \Delta p$)
c. Momentum and its relation to force ($F = \Delta p/\Delta t$)
d. Conservation of momentum ($\Sigma p = \Sigma p'$)
e. Collision and Impulse Problems

f. Elastic collisions in one dimension ($v_1 - v_2 = v_2' - v_1'$)
g. Perfectly inelastic collisions in one dimension ($m' = m_1 + m_2$)
h. Inelastic collisions in one dimension

**5. Work and Energy**

a. Work done by a constant force ($W = Fd_{parallel}$)
b. Conservation of Energy ($E_o + W = E_f$)
c. Kinetic Energy ($KE = ½ mv^2$)
d. Gravitational Potential Energy (GPE = mgh)
e. Elastic Potential Energy ($EPE = ½ kx^2$)
f. Internal Energy and Joule's Principle
g. Conservative and non-conservative forces
h. Problem solving with the Principle of Conservation of Energy.

**6. Electric Charge and Electric Field**

a. Electric charge and its conservation
b. Interactions of charges
c. Induced charges; the electroscope
d. Coulomb's Law ($F = kq_1q_2/r^2$)
e. Electric field ($E = kq/r^2$)
f. Superposition of forces
g. Superposition of electric fields
h. Calculation of net force and/or field due to multiple charges

**7. Electric Potential**

a. Electric potential and potential difference (V = kq/r)
b. Relation between electric potential and field (V = Ed)
c. Equipotential lines
d. Calculation of net electric potential due to multiple charges
e. Calculation of potential energy of a charge in at a voltage
f. Calculation of the potential energy of an assembly of charges

**8. Electric Currents and DC Circuits**

a. The electric battery
b. Electric current ($I = \Delta q/\Delta t$
c. Ohm's Law (I = V/R)
d. Resistivity $R = \rho L/A$
e. Superconductivity
f. Joule's Law and Electric Power ($P=V^2/R = IV = I^2R$)
g. Resistors in series ($R_{series} = R_1 + R_2 +...$)
h. Adding resistors in parallel ($1/R_{parallel} = 1/R_1 + 1/R_2 +...$)
i. Equivalent Circuit resistance
j. Calculating current in circuits and circuit branches
k. Calculating power in circuits and circuit branches
l. EMF and terminal voltage ($VT = \mathrm{E} - Ir$)
m. EMF's in series and in parallel

**9. Magnetism**

a. Magnets and magnetic fields
b. Electric currents produce magnetic fields
c. Force on an electric current in a magnetic field ($F = LIB_{perpendicular}$)
d. Force on a charged particle in a magnetic field ($F = qvB_{perpendicular}$)
e. Magnetic field due to a current carrying wire $B = \mu_o I/2\pi r$
f. Force between parallel wires $F = \mu_o I_1 I_2/2\pi r$

g. Direction of force between two parallel wires
h. Mass spectrometry (r = mv/(qB))
i. Velocity selection (v = E/B)

**10. Electromagnetic Induction**

a. Magnetic Flux ($\varphi_B = BA_{parallel}$)
b. Magnitude of Induced EMF ($E = -N\Delta\varphi/\Delta\tau$
c. Lenz's Law
d. EMF induced in a moving conductor $E = BvL_{perpendicular}$
e. Changing magnetic flux produces an electric field
f. Electric generators
g. Conversion of mechanical to electric energy and its importance

**11. Simple Harmonic Motion; Vibrations; and Waves**

a. Period and frequency
b. Mass-spring systems
c. The simple pendulum
d. Wave Motion
e. Wavelength, frequency and wave velocity
f. Interference
g. Refraction
h. Diffraction
i. Standing Waves

**12. Electromagnetic Radiation and the Wave Nature of Light**

a. Changing electric fields produce magnetic fields
b. Production of EM Waves
c. The Wave Nature of Light
d. Visible Spectrum
e. Dispersion
f. The Speed of Light
g. The Double slit Experiment

**13. Atomic and Nuclear Physics**

a. Alpha particle scattering and the Rutherford model of the atom
b. Photons and the photoelectric effect
c. Wave-particle duality
d. Bohr model of the atom

**14. Fluids**

a. Property called density.
b. tension, friction, normal, spring, and buoyant
c. Interatomic electric forces
d. Bernoulli's equation

**15. Geometric Optics**

a. Ray diagrams
b. Qualitative and quantitative reasoning
c. Snell's Law
d. Ray diagrams
e. Light reflects and refracts on and through surfaces.
f. Draw ray diagrams

**III. Required Labs**

Physics Framework: New Jersey Core Curriculum Content Standards for Science

1. Graphical analysis of the motion of an object
2. Position, velocity, acceleration
3. Kinetic friction
4. Inertia
5. Centripetal force
6. Conservation of momentum
7. Electric charge
8. Electric field
9. Ohm's Law
10. Series and parallel circuits
11. Resistivity
12. Magnetic field maps
13. SHM spring-mass oscillating system

## IV. Course Assessment

Formative assessments are done by the teacher in order to assure that the students understand the material that has been taught. These occur during class and divide into two categories. The first category is ungraded and consists of student participation, student responses to questions, observed student-student interactions and homework completion.

The second type of formative assessment is graded and consists of quizzes, based on previously discussed homework assignments; quests, which are full period assessments that check a broader set of problems at the same level of difficulty as quizzes; and reading quizzes, which check to see if students have been completing reading assignments. Altogether these assessments represent about 20 - 30% of the marking period grade.

Summative assessments take the form of chapter tests, midterms and finals. These are all given in the same form as the AP exam; half multiple choice and half free response. The multiple choice questions are conceptual in nature while the free response section involves solving multistep problems; often taken from prior AP exams. Chapter tests comprise about 50 - 60% of each marking period grade. The midterm and final exam each represent 10% of the full year grade; combined they equal a marking period grade.

The intention is for identical summative assessments to be given to all the students in the course on the same day, regardless of their teacher. This is to encourage students to study together in groups, with or without a teacher, to advance their skill and understanding.

Laboratory work is graded and typically represents about 20% of each marking period grade. The grade is divided evenly between the work done in the lab, based on teacher observation, and the lab report.

## V. Methodology

Lecture

Use of this method will be limited to the introduction of new topics and will be of short duration, no more than 10 minutes in one class period. Many classes will not include this component at all. The students will need to use their visual, listening, writing skills and organization skills to benefit from this part of the course. Students will be required to keep complete and organized notebooks

Large group Problem Solving and Discussion Sessions

The teacher will lead these sessions where students will actively participate in raising questions, answering questions and expanding upon topics. The entire class will work together to solve complex problems which test their understanding of the ideas being developed. The teacher will coordinate these sessions to ensure that all the students participate. This is vital in that this gives each student the opportunity to expand their understanding. By increasing the Zone of Proximal Development (ZPD) for all the students, they will be able to quickly advance their understanding.

Physics Framework: New Jersey Core Curriculum Content Standards for Science

Small Group Problem Solving Sessions
In these sessions a few problems will be given to the entire class and they will work in groups of 2 to 4 students to solve them. Once most of the problems have been solved, each group will present a solution to one of the problems to the rest of the class. Disputes and different approaches will be discussed in the Large Group format with the class taking the lead in determining the best approach. The teacher serves to chair the discussion. Once again this activity is designed to allow the students to quickly learn in an environment where their ZPD has been expanded.

Hands-On Activities / Laboratory / Discovery
Students participate in labs on alternate weeks. Each lab period is 86 minutes long, giving students the time necessary to take all data and begin analysis in groups.

Students need to not only solve problems analytically but also apply those solutions to real hands on problems. These sessions are generally, but not exclusively, held in the physics laboratory and involve two to four students working together. The students will be asked to conduct experiments that either apply or develop new understandings. These will not be cookbook experiments, where the students simply walk through a procedure. Rather, these experiments involve gathering data and making analyses where the results are unknown to them, and sometimes even to the instructor.

These labs will use actual physical apparatus, often with electronic probes to gather data and computers to conduct analysis. Whenever possible, they will be performed towards the beginning of each unit, affording the student the experience of discovering the concepts before they are formally taught by the instructor. One objective of each lab exercise is for each student to analyze their data using data and error analysis techniques in order to judge the accuracy and meaning of their results.

Reading
Students will be encouraged to develop the self-confidence and techniques required to learn directly from the text. The techniques needed to accomplish that will be discussed in class and reviewed from time to time. Readings will be assigned to either introduce or reinforce topics. In this way, classroom time is not spent reviewing every fact and detail for which the students will be responsible. Students will then be better prepared to participate and engage in active classroom discussion. The skill of being able to read and understand a text is so critical that great effort will be made to encourage students to develop it. In this vein, reading quizzes will be given from time to time to determine that students are completing their reading assignments.

Homework problems
Problems will be assigned every night so that students can apply the learning that was done during class that day. This will be checked by periodic homework quizzes that will be given the day after the assignment was due. In that way, student who made an honest effort but need to ask questions in class to reach a correct solution are not penalized. The homework quizzes are designed to test that students are learning how to do these problems. This contrasts with collecting assignments, which can lead to copying rather than understanding.

# Unit 1: One-Dimensional Kinematics

## NGSS DCI:

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

## AP Physics 1 and 2 Standards

- Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- Science Practice 2: The student can use mathematics appropriately.
- Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
- Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How vectors are used to analyze motion?<br>2. What is the difference between speed and velocity?<br>3. What are the relationships between position, velocity, and acceleration? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will:<br>• understand the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line.<br>• understand the special case of motion with constant acceleration.<br>• understand the relationship among words, equations and graphs for motion in on dimension. | By the end of this unit, students will be able to:<br>• solve problems specifically by first writing out all variables present, determining the appropriate equation to use, solving the equation for the variable needed, inserting numbers into the equation, and finally performing calculations with a scientific calculator.<br>• apply the qualitative definition of acceleration (speeding up, or slowing down, and/or changing direction) to determine if an object is accelerating.<br>• Students will be able to determine velocity by taking the slope of a position-time graph, and determine acceleration from the slope of a velocity-time graph, as well as the displacement by calculating the area under the curve.<br>• Students will correlate negative and positive slopes with positive and negative velocities and accelerations. |

# Unit 2: Dynamics

## NGSS DCI:

- HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]
- HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]
- HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.][Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

## AP Physics 1 and 2 Standards

- Essential Knowledge 3.A.2: Forces are described by vectors.
  - a. Forces are detected by their influence on the motion of an object.
  - b. Forces have magnitude and direction.
- Learning Objective (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.
- Essential Knowledge 3.A.3: A force exerted on an object is always due to the interaction of that object with another object.
  - a. An object cannot exert a force on itself.
  - b. Even though an object is at rest, there may be forces exerted on that object by other objects.
  - c. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.
- Learning Objective (3.A.3.1): The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.
- Learning Objective (3.A.3.2): The student is able to challenge a claim that an object can exert a force on itself.
- Learning Objective (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.
- Essential Knowledge 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.
- Learning Objective (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.
- Learning Objective (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.
- Learning Objective (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.

- Essential Knowledge 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
- Learning Objective (3.B.1.1): 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 with acceleration in one dimension.
- Learning Objective (3.B.1.2): The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.
- Learning Objective (3.B.1.3): The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.
- Learning Objective (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.
- Essential Knowledge 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  a. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  b. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  c. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.
- Learning Objective (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.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How can an object be made to accelerate?<br>2. How do forces interact?<br>3. How do objects respond to multiple forces acting on them? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• How to apply the concept of inertia to determine the motion of an object experiencing a net force and zero net force.<br>• How to algebraically manipulate and utilize the following equations:<br>$\Sigma F = ma$<br>$f_k = \mu_k F_N$<br>$f_s < \mu_s F_N$<br>$w = mg$<br>• How to solve problems specifically by first sketching the setup, drawing a free body diagram, determining the forces present, aligning coordinate axes, solving the equation for the variable needed, inserting | By the end of this unit, students will be able to:<br>• Describe inertia using Newton's First Law.<br>• Relate force, mass and acceleration using Newton's Second Law.<br>• Solve problems using Newton's Second Law.<br>• Describe inertial reference frames.<br>• Differentiate between weight and mass.<br>• Describe weight as a force in terms of mass and gravitational acceleration.<br>• Describe the normal force and understand the conditions in which it exists.<br>• Identify a reaction force if given an action force. |

| | |
|---|---|
| numbers into the equation, and finally performing calculations with a scientific calculator.<br>• How to determine the weight of objects in settings with vertical accelerations and determine the difference between true weight and apparent weight (normal force).<br>• How apply Newton's Third Law (for every action force, there is an equal and opposite reaction force) to determine action/reaction pairs.<br>• How to identify when friction must be considered in a problem and when it can be ignored, determine the type of friction present, and the point at which the static friction is overcome to result in kinetic friction.<br>• How to identify all the different types of force present in a problem. They will draw the relative magnitudes and directions of the forces on a free body diagram and note the direction of acceleration<br>• How to, after drawing a free body diagram, students will apply Newton's Second Law to a problem, determining the net force acting on an object. They will solve for net forces and forces specific to the problem.<br>• How to identify the following forces and illustrate their relative magnitudes and directions when problem solving:<br>  ◦ Applied Force<br>  ◦ Normal Force<br>  ◦ Weight (Gravitational Force)<br>  ◦ Apparent Weight<br>  ◦ Tension<br>  ◦ Friction (Kinetic and Static)<br>How to solve Atwood machine type problems. | • Determine whether a frictional force is kinetic (moving) or static (not moving).<br>• Solve problems involving static and kinetic friction.<br>• Identify and solve for tension force.<br>• Draw free body diagrams.<br>• Solve problems involving multiple forces and accelerations not restricted to one axis of motion. |

# Unit 3: Uniform Circular Motion

## NGSS DCI:

The topics in this unit are an essential part of understand the later units and of physics as a whole.

## AP Physics 1 and 2 Standards

This essential knowledge does not produce a specific learning objective but serves as a foundation for other learning objectives in the course.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How do we use Free Body diagrams and Newton's Laws to solve circular motion problems?<br>2. What are the applications of circular motion?<br>3. How does apparent weight vary during circular motion? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• How to relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.<br>• How to describe the direction of the particle's velocity and acceleration at any instant during the motion.<br>• How to analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following:<br>(1) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).<br>(2) Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel). | By the end of this unit, students will be able to:<br>• Learn various concepts and ideas related to circular motion. They will use the following equations in solving problems.<br>  • $a = v^2/r$<br>  • $v = 2\pi r/T$<br>  • $T = 1/f$<br>  • $F = ma$ |

# Unit 4: Linear Momentum

## NGSS DCI:

- HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
- HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

## AP Physics 1 and 2 Standards

- Enduring Understanding 3.D: A force exerted on an object can change the momentum of the object.
- Essential Knowledge 3.D.1: The change in momentum of an object is a vector in the direction of the net force exerted on the object.
- Learning Objective (3.D.1.1): The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.
- Essential Knowledge 3.D.2: The change in momentum of an object occurs over a time interval.
  a. The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object).
  b. The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.
- Learning Objective (3.D.2.1):The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.
- Learning Objective (3.D.2.2):The student is able to predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Learning Objective (3.D.2.3):The student is able to analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Learning Objective (3.D.2.4):The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.

| Essential Questions | |
|---|---|
| **(What questions will the student be able to answer as a result of the instruction?)** | |
| 1. How do we determine the impulse on a physical system when the forces on the system, and the time interval these forces act, are known?<br>2. What is the difference between elastic and inelastic collisions? | |
| Knowledge & Skills | |
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• relationship between certain physics quantities related to impulse and momentum.<br>• fundamental law of physics -conservation of momentum. | By the end of this unit, students will be able to:<br>• use the following equations in solving problems:<br><br>P = mv<br>Momentum<br><br>I = Δp = mv Impulse |

# Unit 5: Work and Energy

## NGSS DCI:

- 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-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

## AP Physics 1 and 2 Standards

- Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.
- Essential Knowledge 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the interval that the force is exerted.
  a. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object.
  b. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to the displacement.
  c. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion.
- Learning Objective (3.E.1.1):The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.
- Learning Objective (3.E.1.2):The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged.
- Learning Objective (3.E.1.3):The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged.
- Learning Objective (3.E.1.4):The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object.
- Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.
- Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.
  a. If the force is constant during a given displacement, then the work done is the product of the displacement and the component of the force parallel or antiparallel to the displacement.
  b. Work (change in energy) can be found from the area under a graph of the magnitude of the force component parallel to the displacement versus displacement.
- Learning Objective (4.C.2.1):The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.
- Learning Objective (4.C.2.2):The student is able to apply the concepts of Conservation of Energy and the Work-Energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

- Enduring Understanding 5.A: Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.
- Essential Knowledge 5.A.1: A system is an object or a collection of objects. The objects are treated as having no internal structure.
- Essential Knowledge 5.A.2: For all systems under all circumstances, energy, [charge, linear momentum, and angular momentum] are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
- Essential Knowledge 5.A.3: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.
- Essential Knowledge 5.A.4: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.
- Enduring Understanding 5.B: The energy of a system is conserved.
- Essential Knowledge 5.B.1: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.
- Learning Objective (5.B.1.1):The student is able to set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.
- Learning Objective (5.B.1.2):The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.
- 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.
- Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
- a. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the 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 energy transfer 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.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How do we determine the work done on a physical system when the net force acting on it and its displacement are known?<br>2. How do we use the work/energy theorem to determine the motion of an object?<br>3. How do we apply energy conservation to determine the position and motion of an object? |
| Knowledge & Skills |
| **(What skills are needed to achieve the desired results?)** |

| By the end of this unit, students will know: | By the end of this unit, students will be able to: |
|---|---|
| • Definition of work, including when it is positive, negative, or zero.<br>• How to apply the work-energy theorem.<br>• The concept of a conservative force.<br>• The concept of potential energy.<br>• The concepts of mechanical energy and of total energy.<br>• Conservation of energy.<br>• The definition of power. | • Calculate the work done by a specified constant force on an object that undergoes a specified displacement.<br>• Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.<br>• Use the scalar product operation to calculate the work performed by a specified constant force F on an object that undergoes a displacement in a plane.<br>• Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.<br>• Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.<br>• Apply the theorem to determine the change in an object's kinetic energy and speed which results from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.<br>• Describe examples of conservative forces and non-conservative forces.<br>• Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.<br>• Calculate the potential energy of one or more objects in a uniform gravitational field.<br>• State and apply the relation between the work performed on an object by non-conservative forces and the change in an object's mechanical energy.<br>• Describe and identify situations in which mechanical energy is converted to other forms of energy.<br>• Analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force.<br>• Identify situations in which mechanical energy is or is not conserved.<br>• Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine.<br>• Apply conservation of energy in analyzing the motion of objects that move under the influence of springs.<br>• Recognize and solve problems that call for application both of conservation of energy and Newton's Laws.<br>• Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed).<br>• Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work. |

# Unit 6: Electric Charge and Force

## NGSS DCI:

- 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.A.4: Atoms have internal structures that determine their properties.
  - a. The number of protons in the nucleus determines the number of electrons in a neutral atom.
  - b. The number and arrangements of electrons cause elements to have different properties.
- Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.
- 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.
- Learning Objective (1.B.1.1): The student is able to make claims about natural phenomena based on conservation of electric charge.
- 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.
- 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 $1.6 x 10^{19}$ 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.

| Essential Questions |
| --- |
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How many types of electric charge are there? What are they named?<br>2. Which particle of an atom carries a positive charge? Which carries the negative charge?<br>3. Why is it that when you take off a sweater in a dark room you can see tiny sparks and hear a crackling sound?<br>4. Compare and contrast Coulomb's Law with Newton's Law of Universal Gravitation.<br>5. 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? |

| Knowledge & Skills |
| --- |
| **(What skills are needed to achieve the desired results?)** |

| By the end of this unit, students will know: | By the end of this unit, students will be able to: |
| --- | --- |
| • The two types of electric charges<br>• The law of conservation of charge<br>• How charges interact<br>• How to charge various object using conduction and induction | • Use Coulomb's Law to solve problems<br>• Make predictions about charges |

# Unit 7: Electric Potential

## NGSS DCI:

Exceeds Standards

## AP Physics 1 and 2 Standards

- Essential Knowledge 1.E.4: Matter has a property called electric permittivity.
  a. Free space has a constant value of the permittivity that appears in physical relationships.
  b. The permittivity 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.
- 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 about the number, relative size, and location of sources.
- 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.
- Enduring Understanding 2.C: An electric field is caused by an object with electric charge.
- Essential Knowledge 2.C.1: The magnitude of the electric force F exerted on an object with electric charge q by an electric field E is F=qE. The direction of the force is determined by the direction of the field and the sign of the charge, 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 distribution, 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=q E; 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 semi-quantitatively 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

$$E=kQr2$$

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 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.
- 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.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. What is the definition of the Electric Field and what equation was used to derive this concept?<br>2. Why can Electric Field lines never cross or touch each other? Do Electric Field lines exist?<br>3. What is the significance of the density of the electric field lines about a charge?<br>4. How is the Electric Potential derived from the Electric Potential Energy?<br>5. What is an equipotential line? How does it relate to an Electric Field line? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• How to define electric fields and how they relate to electric force.<br>• The relationship between electric potential, voltage and potential | By the end of this unit, students will be able to:<br>• Use the following equations to solve problems:<br>$E=kQ/r^2$ $F=qE$ $V=kQ/r$ $UE=qV$ $E=\Delta V/x$ |

| | |
|---|---|
| energy.<br>• How charged objects respond to electric fields and potential differences. | |

# Unit 8: Electric Currents and DC Circuits

**NGSS DCI:** This unit provides necessary background and skills for the following unit on current and circuits

## 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.1.2): 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.E.2: Matter has a property called resistivity.
  a. The resistivity of a material depends on its molecular and atomic structure.
  b. The resistivity depends on the temperature of the material.
- Learning Objective (1.E.2.1): The student is able to choose and justify the selection of data needed to determine resistivity for a given material.
- 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, $\kappa$, of the material between the plates and the electric permittivity, $\varepsilon_o$.
  c. The current through a resistor is equal to the potential difference across the resistor divided by its resistance R. 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.

- Essential Knowledge 5.B.9: Kirchhoff 's loop rule describes conservation of energy in electrical circuits. The application of Kirchhoff's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.
  - a. Energy changes in simple electrical circuits are conveniently represented in terms of energy change per charge moving through a battery and a resistor.
  - b. Since electric potential difference times charge is energy, and energy is conserved, the sum of the potential differences about any closed loop must add to zero.
  - c. The electric potential difference across a resistor is given by the product of the current and the resistance.
  - d. The rate at which energy is transferred from a resistor is equal to the product of the electric potential difference across the resistor and the current through the resistor.
  - e. Energy conservation can be applied to combinations of resistors and capacitors in series and parallel circuits.
- Learning Objective (5.B.9.1): The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff 's loop rule).
- Learning Objective (5.B.9.2): The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ($\sum \Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.
- Learning Objective (5.B.9.3): The student is able to apply conservation of energy (Kirchhoff 's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch.

## Essential Questions

**(What questions will the student be able to answer as a result of the instruction?)**

1. What are voltage, current, and resistance?
2. How are voltage, current, and resistance related?
3. What factors affect resistivity?

## Knowledge & Skills

**(What skills are needed to achieve the desired results?)**

| By the end of this unit, students will know: | By the end of this unit, students will be able to: |
|---|---|
| • That current is defined as charge over time<br>• The relationship between voltage, current, and resistance<br>• Ohm's Law<br>• Kirchoff's Rules (the rules will not be named but they will be applied)<br>• The relationship between voltage/current/resistance and power in circuits<br>• The relationship between emf and terminal voltage | • Use the following equations to solve problems with simple DC circuits:<br>I=Qt R=ρLA I=VR P=IV=V2R=I2R<br>Req in series=R1+R2+R3+…<br>1Req in parallel=1R1+1R2+1R3+…<br>VT=ε-Ir |

# Unit 9: Magnetism

## NGSS DCI:

- 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.

### Essential Questions

**(What questions will the student be able to answer as a result of the instruction?)**

1. Both Electric and Magnetic Forces will cause objects to repel and attract each other. What is a difference in the origin of these forces?
2. A Magnet has a north and a south pole. If you cut the magnet in half, describe what happens to each end of the two pieces.
3. Can you find a magnet with just a north pole?
4. What Field circles a current carrying wire?

### Knowledge & Skills

**(What skills are needed to achieve the desired results?)**

| By the end of this unit, students will know: | By the end of this unit, students will be able to: |
|---|---|
| • How to determine the direction of the magnetic field created by a current carrying wire.<br>• How to determine the force exerted by a magnetic field on a moving charged particle or current carrying wire. | • Find the magnitude of the magnetic field created by a current carrying wire using: $B=\mu 0I2\pi r$<br>• Find the magnitude of the force exerted by a magnetic field on a current carrying wire using: $FB=ILB$<br>• Find the magnitude of the force exerted by a magnetic field on a moving charge: $FB=qvB$<br>• Find the magnitude of the force between tow current carrying wires using: $FB=\mu 0I1I2l2\pi r$ |

# Unit 10: EM Induction

## NGSS DCI:

- 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>
<tr><td colspan="2" align="center">Essential Questions</td></tr>
<tr><td colspan="2">(What questions will the student be able to answer as a result of the instruction?)</td></tr>
<tr><td colspan="2">1. What did Michael Faraday’s experiment demonstrate?<br>2. Using Faraday’s Law of Induction, explain how a constant magnetic field can still generate an EMF in a closed loop.<br>3. What is Lenz’s Law?</td></tr>
<tr><td colspan="2" align="center">Knowledge & Skills</td></tr>
<tr><td colspan="2">(What skills are needed to achieve the desired results?)</td></tr>
<tr><td>By the end of this unit, students will know:<br>• That an electric current induces a magnetic field.<br>• That a changing magnetic field induces an EMF.<br>• How to determine the direction of the induced current.</td><td>By the end of this unit, students will be able to:<br>• Determine the flux, induced EMF, and current using the equations:<br>$\Phi=BA$<br>$\varepsilon=-N\Delta\Phi\Delta t$<br>$\varepsilon=Blv$<br>$I=\varepsilon R$<br>• Determine the direction of the induced current using Lenz’s Law.</td></tr>
</table>

# Unit 11: Simple Harmonic Motion, Vibrations, and Waves

## NGSS DCI:

- 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-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
- HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

## AP Physics 1 and 2 Standards

- Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion.
  a. For a spring that exerts a linear restoring force the period of a mass-spring oscillator increases with mass and decreases with spring stiffness.
  b. For a simple pendulum oscillating the period increases with the length of the pendulum.
  c. Minima, maxima, and zeros of position, velocity, and acceleration are features of harmonic motion. Students should be able to calculate force and acceleration for any given displacement for an object oscillating on a spring.
- Learning Objective (3.B.3.1):The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.
- Learning Objective (3.B.3.2): The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.
- Learning Objective (3.B.3.3):The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.
- Learning Objective (3.B.3.4):The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.
- Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.
- Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.
  a. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves.
  b. Electromagnetic waves are transverse waves.
  c. Transverse waves may be polarized.
- Learning Objective (6.A.1.1): The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.
- Learning Objective (6.A.1.2): The student is able to describe representations of transverse and longitudinal waves.
- Learning Objective (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.

- Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.
- Learning Objective (6.A.3.1): The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.
- Learning Objective (6.A.4.1):The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.
- Enduring Understanding 6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy. Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.
- Learning Objective (6.B.1.1):The student is able to use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.
- Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.
- Learning Objective (6.B.2.1):The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.
- Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.
- Learning Objective (6.B.4.1):The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.
- Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.
- Essential Knowledge 6.C.1: When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.
- Learning Objective (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.
- Learning Objective (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.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. What is simple harmonic motion?<br>2. How do we determine the energy, position, speed, acceleration, frequency, and period of a physical system?<br>3. What are the properties of waves?<br>4. How do we distinguish the difference between longitudinal and transverse waves, and give at least one example of each?<br>5. What happens when two waves overlap? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• How energy changes from potential to kinetic during simple harmonic motion<br>• How a spring pendulum works<br>• How a simple pendulum work | By the end of this unit, students will be able to:<br>• Use the following equations to solve problems involving a simple pendulum or a spring pendulum:<br>$T=tn=1f \quad f=nt=1T$<br>$T=2\pi Lg \quad T=2\pi mk$ |

| | |
|---|---|
| • Various concepts dealing with vibrations and waves.<br>• The difference between longitudinal and transverse waves.<br>What happens when waves interact? | KE=12mv2 GPE=mgh EPE=12kx2<br><br>By the end of this unit, students will be able to:<br>• Solve problems involving waves using the following equations:<br>v=λT=λf<br>v=FTμ<br>λ=2Ln |

## Unit 12: Electromagnetic Radiation and the Wave

# Nature of Light

## NGSS DCI:

- 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.

Essential Questions

**(What questions will the student be able to answer as a result of the instruction?)**

1. How does light behave like a wave?
2. How do we identify the electromagnetic spectrum?
3. How does wave speed relate to frequency?

Knowledge & Skills

**(What skills are needed to achieve the desired results?)**

| By the end of this unit, students will know: | By the end of this unit, students will be able to: |
|---|---|
| • The wave properties of light<br>• The double slit and single slit experiments<br>• How light changes speed and direction when entering a new medium | • Solve various problems relating to light in double slit experiments and thin films using the following equations:<br>$c=\lambda f$<br>$n=cv$<br>$x=m\lambda Ld$<br>$2t=m\lambda$ and $2t=(m+12)\lambda$ |

Assessment

**(What is acceptable evidence to show desired results (rubrics, exam, etc.)? Attach Copy**

During the Smart Notebook lesson designed to introduce concepts, students will be continually questioned on these concepts using a combination of class work/homework questions and the SMART Response system. Classwork and Homework questions will be discussed as a class and misconceptions will be addressed by the teacher prior to the formal evaluations listed below.

- EM Wave Test

Other assessments on the NJCTL website are optional and can be used as needed.

## Unit 13: Atomic and Nuclear Physics

## NGSS DCI:

- 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**.**
- 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 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 m= c2
  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.
- Essential Knowledge 6.F.3: Photons are individual energy packets of electromagnetic waves, with Ephoton = hf, where h is Planck's constant and f is the frequency of the associated light wave.
- 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 Ephoton.
  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.)

| Essential Questions |
| --- |
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. What particles make up the nucleus? What is the general term for them? What are those particles composed of?<br>2. What is the definition of the atomic number? What is its symbol?<br>3. What is the definition of the atomic mass number? What is its symbol?<br>4. What is the definition of mass defect?<br>5. What is the definition of binding energy?<br>6. What is the spontaneous emission of radiation from nuclei called? What are the three types?<br>7. What is nuclear fusion and where does it occur?<br>8. Who determined the charge on an electron, and what was the name of the experiment?<br>9. What assumption did Max Planck make to solve the Blackbody radiation problem? |

10. What properties of the Photoelectric effect could not be explained by the wave theory of light?
11. How did Albert Einstein explain the Photoelectric effect? Who first postulated that light was made up of particles?
12. Describe the Thomson Plum Pudding model of the atom.
13. What experiment was performed by Ernest Rutherford? How did it change the Thomson model?
14. How did Neils Bohr resolve the problems with the Rutherford model?

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• Mass defect and binding energy<br>• Alpha decay<br>• Beta decay<br>• Gamma Radiation<br>• Fission<br>• Fusion<br>• The Oil Drop Experiment<br>• Rutherford's Experiment<br>• The Cathode Ray Tube Experiment<br>• The Photoelectric Effect<br>• The Bohr Model of the Atom | By the end of this unit, students will be able to:<br>• Solve problems using the following equation: $E=\Delta mc2$<br>• Solving problems involving nuclear reactions<br>• Solve problems using the following equations: $E=hf$ $hf=\emptyset+KE$<br>• $KE=eV0$ $\lambda=h/p$ |

## Unit 14: Fluids

## NGSS DCI:

- 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.

<table>
<tr><th colspan="2">Essential Questions</th></tr>
<tr><th colspan="2">(What questions will the student be able to answer as a result of the instruction?)</th></tr>
<tr><td colspan="2">1. How is density defined?<br>2. What is the difference between gauge pressure and absolute pressure?<br>3. How do hydraulic lifts work?<br>4. What is the buoyant force?<br>5. How do water speeds vary in pipes?</td></tr>
<tr><th colspan="2">Knowledge & Skills</th></tr>
<tr><th colspan="2">(What skills are needed to achieve the desired results?)</th></tr>
<tr><td>By the end of this unit, students will know:<br>• Density<br>• Specific Gravity<br>• Pressure in Fluids<br>• Atmospheric Pressure and Gauge Pressure<br>• Pascal's Principle<br>• Buoyancy and Archimedes' Principle<br>• Fluids in Motion and Bernoulli's Principle<br>• Torricelli's Theorem</td><td>By the end of this unit, students will be able to:<br>• Use the following equations to solve problems:<br>$\rho=mV$<br>$SG=\rho\rho water$<br>$P=FA$<br>$P=\rho gh$<br>$FB=\rho fluidgV=mfluidg$<br>$\rho 1A1v1=\rho 2A2v2$</td></tr>
</table>

| | |
|---|---|
| | $P+12\rho v2+\rho gh=\text{constant}$ |

# Unit 15: Geometric Optics

## NGSS DCI:

- 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.

| Essential Questions |
|---|
| **(What questions will the student be able to answer as a result of the instruction?)** |
| 1. How does light refract and reflect off boundaries?<br>2. How do concave and convex mirrors work?<br>3. How do converging and diverging lenses work? |

| Knowledge & Skills | |
|---|---|
| **(What skills are needed to achieve the desired results?)** | |
| By the end of this unit, students will know:<br>• How to draw ray diagrams to find the location of an image. | By the end of this unit, students will be able to:<br>• Find the height and location of an image using the follow equations:<br>$1f=1do+1di$<br>$m=-dido=hiho$<br>$c=\lambda f$ |

Instructional Resources / Material: www.njctl.org