# Plymouth Public Schools' Science and Technology/Engineering Program
# High School Physics Learning Standards

STE0053 Physics College Prep 1

## An Introduction to the Massachusetts Department of Elementary and Secondary Education Science and Technology/Engineering Curriculum Framework

Effective teaching and learning in science fosters engagement and has rigor, relevance, and coherence embedded within. It couples practice with content to give the context for performance. A program with these components encourages students to analyze and explain phenomena and experience; engages with practices to build, use, and apply knowledge; and builds a storyline over time and among disciplines. The state standards that form this program are outcomes that reflect what a student should know and be able to do as a result of instruction. Science and engineering practices, which are included in these standards, are not teaching strategies; they are important learning goals and skills to be learned, also as a result of instruction. The standards listed below are not intended to represent an exhaustive list of all that could be included in our district's science program, nor should this list prevent students from going beyond the standards where appropriate. (Excerpts from Curriculum Framework)

## Disciplinary Core Ideas – Physics

Introductory physics standards build from middle school to explain additional and more complex phenomena central to the physical world. More specifically, these standards help students understand why some objects move in certain ways, why objects change their motion, and why some materials are attracted to each other while others are not. Students will also work towards developing an explanation for the phenomena related to energy at both the macroscopic and atomic scales that can be accounted for as either motions of particles or energy stored in fields. In addition, standards on wave properties and the interactions of electromagnetic radiation with matter are included, as well as how these waves and their interactions can transfer information across long distances, store information, and investigate nature on many scales. Particular emphasis is placed on developing and using models, analyzing and interpreting data, using mathematics, and engaging in argument from evidence. (Excerpts from Curriculum Framework)

## PS2. Motion and Stability: Forces and Interactions

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force.

Clarification Statements:

1. 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, and a moving object being pulled by a constant force.
2. Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.

State Assessment Boundary:
Variable forces are not expected in state assessment.

HS-PS2-2. Use mathematical representations to show that the total momentum of a system of interacting objects is conserved when there is no net force on the system.

Clarification Statement:
Emphasis is on the qualitative meaning of the conservation of momentum and the quantitative understanding of the conservation of linear momentum in interactions involving elastic and inelastic collisions between two objects in one dimension.

HS-PS2-3. Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Clarification Statement:
Both qualitative evaluations and algebraic manipulations may be used.

HS-PS2-4. Use mathematical representations of Newton's law of gravitation and Coulomb's law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.

Clarification Statement:
Emphasis is on the relative changes when distance, mass or charge, or both are changed.

State Assessment Boundaries:

1. State assessment will be limited to systems with two objects.
2. Permittivity of free space is not expected in state assessment.

HS-PS2-5. Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Clarification Statement:
Examples of evidence can include movement of a magnetic compass when placed in the vicinity of a current-carrying wire, and a magnet passing through a coil that turns on the light of a Faraday flashlight.

State Assessment Boundary:
Explanations of motors or generators are not expected in state assessment.

HS-PS2-9(MA). Evaluate simple series and parallel circuits to predict changes to voltage, current, or resistance when simple changes are made to a circuit.

Clarification Statements:

1. Predictions of changes can be represented numerically, graphically, or algebraically using Ohm's law.
2. Simple changes to a circuit may include adding a component, changing the resistance of a load, and adding a parallel path, in circuits with batteries and common loads.
3. Simple circuits can be represented in schematic diagrams.

State Assessment Boundary:
Use of measurement devices and predictions of changes in power are not expected in state assessment.

HS-PS2-10(MA). Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.

Clarification Statements:

1. Predictions of changes in motion can be made numerically, graphically, and algebraically using basic equations for velocity, constant acceleration, and Newton's first and second laws.
2. Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.

PS3. Energy

HS-PS3-1. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.

Clarification Statement:
Systems should be limited to two or three components and to thermal energy; kinetic energy; or the energies in gravitational, magnetic, or electric fields.

HS-PS3-2. Develop and use a model to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles and objects or energy stored in fields.

Clarification Statements:

1. Examples of phenomena at the macroscopic scale could include evaporation and condensation, the conversion of kinetic energy to thermal energy, the gravitational potential energy stored due to position of an object above the earth, and the stored energy (electrical potential) of a charged object's position within an electrical field.
2. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

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

Clarification Statements:

1. Emphasis is on both qualitative and quantitative evaluations of devices.
2. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators.
3. Examples of constraints could include use of renewable energy forms and efficiency.

State Assessment Boundary:
Quantitative evaluations will be limited to total output for a given input in state assessment.

HS-PS3-4a. Provide evidence that when two objects of different temperature are in thermal contact within a closed system, the transfer of thermal energy from higher temperature objects to lower-temperature objects results in thermal equilibrium, or a more uniform energy distribution among the objects and that temperature changes necessary to achieve thermal equilibrium depend on the specific heat values of the two substances.

Clarification Statement:
Energy changes should be described both quantitatively in a single phase ($Q = mc\Delta T$) and conceptually either in a single phase or during a phase change.

HS-PS3-5. Develop and use a model of magnetic or electric fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative position in a magnetic or electric field, respectively.

Clarification Statements:

1. Emphasis is on the change in force and energy as objects move relative to each other.

2. Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.

PS4. Waves and Their Applications in Technologies for Information Transfer

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling within various media. Recognize that electromagnetic waves can travel through empty space (without a medium) as compared to mechanical waves that require a medium.

Clarification Statements:

1. Emphasis is on relationships when waves travel within a medium, and comparisons when a wave travels in different media.
2. Examples of situations to consider could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.
3. Relationships include $v = \lambda f$, $T = 1/f$, and the qualitative comparison of the speed of a transverse (including electromagnetic) or longitudinal mechanical wave in a solid, liquid, gas, or vacuum.

State Assessment Boundary:
Transitions between two media are not expected in state assessment.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model, and that for some situations involving resonance, interference, diffraction, refraction, or the photoelectric effect, one model is more useful than the other.

Clarification Statement:
Emphasis is on qualitative reasoning and comparisons of the two models.

State Assessment Boundary:
Calculations of energy levels or resonant frequencies are not expected in state assessment.

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.

Clarification Statements:

1. Emphasis is on qualitative information and descriptions.

2. Examples of technological devices could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.
3. Examples of principles of wave behavior include resonance, photoelectric effect, and constructive and destructive interference.

State Assessment Boundary:
Band theory is not expected in state assessment.