Essential Learning Targets for High School Physics

based on the Michigan High School Content Expectations

Essential Learning Targets represent the foundational knowledge and skills in a subject that are needed for life-long use. They are based on the Michigan *High School Physics Standards and Content Expectations*.

The *High School Physics Standards* represent the overarching, enduring understandings and key skills in the High School Content Expectations (HSCEs) for Physics. There are four standards and 127 content expectations in the HSCEs.

The Essential Learning Targets for Physics include only the most central and necessary ("essential") learning targets for Physics. There are a total of 32 essential learning targets for Physics.

On the following pages, each Standard is listed, followed by a numbered list of essential learning targets. These essential learning targets represent the minimum required of students who have a personal curriculum modification based on their IEP status. Participation by the student's Physics teacher is necessary when using this document to determine a personal curriculum modification.

The codes are from the Michigan High School Content Expectations for Physics.

Standard 1: Inquiry, Reflection and Social Implications – Students will understand the nature of science and demonstrate an ability to practice scientific reasoning by applying it to the design, execution, and evaluation of scientific investigations. Students will demonstrate their understanding that scientific knowledge is gathered through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. They will use their scientific knowledge to assess the costs, risks, and benefits of technological systems as they make personal choices and participate in public policy decisions. These insights will help them analyze the role science plays in society, technology, and potential career opportunities.

Scientific Inquiry

Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.

Essential Learning Targets – Students will be able to:

1) Generate new questions that can be investigated in the laboratory or field. (B1.1A)
2) Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions. (B1.1B)
3) Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity–length, volume, weight, time interval, temperature–with the appropriate level of precision). (B1.1C)

4) Identify patterns in data and relate them to theoretical models. (B1.1D)
5) Describe a reason for a given conclusion using evidence from an investigation. (B1.1E)

Scientific Reflection and Social Implications

The integrity of the scientific process depends on scientists and citizens understanding and respecting the "Nature of Science." Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.

Essential Learning Targets – Students will be able to:

6) Critique whether or not specific questions can be answered through scientific investigations. (B1.2A)
7) Identify and critique arguments about personal or societal issues based on scientific evidence. (B1.2B)
8) Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information. (B1.2C)
9) Evaluate scientific explanations in a peer review process or discussion format. (B1.2D)
10) Evaluate the future career and occupational prospects of science fields. (B1.2E)

Standard 2: Motion of Objects – The universe is in a state of constant change. From small particles (electrons) to the large systems (galaxies) all things are in motion. Therefore, for students to understand the universe they must describe and represent various types of motion. Kinematics, the description of motion, always involves measurements of position and time. Students must describe the relationships between these quantities using mathematical statements, graphs, and motion maps. They use these representations as powerful tools to not only describe past motions but also predict future events.

2.1 Position — Time

An object's position can be measured and graphed as a function of time. An object's speed can be calculated and graphed as a function of time.

Essential Learning Targets – Students will be able to:

1) Calculate the average speed of an object using the change of position and elapsed time. Represent the velocities for linear and circular motion using motion diagrams (arrows on strobe pictures). (P2.1A, P2.1B)
2) Create line graphs using measured values of position and elapsed time. Describe and analyze the motion that a position-time graph represents, given the graph. (P2.1C, P2.1D)
3) Describe and classify various motions in a plane as one dimensional, two dimensional, circular, or periodic. Distinguish between rotation and revolution and describe and contrast the two speeds of an object like the Earth. (P2.1E P2.1F)

2.2 Velocity — Time

The motion of an object can be described by its position and velocity as functions of time and by its average speed and average acceleration during intervals of time.

Essential Learning Targets – Students will be able to:

1) Use the change of speed and elapsed time to calculate the average acceleration for linear motion. (P2.2B)
2) Describe and analyze the motion that a velocity-time graph represents, given the graph. (P2.2C)

Standard 3: Forces and Motion – Students identify interactions between objects either as being by direct contact (e.g., pushes or pulls, friction) or at a distance (e.g., gravity, electromagnetism), and to use forces to describe interactions between objects. They recognize that non-zero net forces always cause changes in motion (Newton's first law). These changes can be changes in speed, direction, or both. Students use Newton's second law to summarize relationships among and solve problems involving net forces, masses, and changes in motion (using standard metric units). They explain that whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted back on it (Newton's third law).

3.1 Basic Forces in Nature

Objects can interact with each other by "direct contact" (e.g., pushes or pulls, friction) or at a distance (e.g., gravity, electromagnetism, nuclear).

Essential Learning Targets – Students will be able to:

1) Identify the force(s) acting between objects in "direct contact" or at a distance. (P3.1A)

3.2 Net Forces

Forces have magnitude and direction. The net force on an object is the sum of all the forces acting on the object. Objects change their speed and/or direction only when a net force is applied. If the net force on an object is zero, there is no change in motion (Newton's First Law).

Essential Learning Targets – Students will be able to:

1) Identify the magnitude and direction of everyday forces (e.g., wind, tension in ropes, pushes and pulls, weight). Calculate the net force acting on an object. (P3.2A, P3.2C)
2) Compare work done in different situations. (P3.2B)

3.4 Forces and Acceleration

The change of speed and/or direction (acceleration) of an object is proportional to the net force and inversely proportional to the mass of the object. The acceleration and net force are always in the same direction.

Essential Learning Targets – Students will be able to:

1) Predict the change in motion of an object acted on by several forces. Solve problems involving force, mass, and acceleration in linear motion (Newton's second law). (P3.4A, P3.4C)
2) Identify forces acting on objects moving with constant velocity (e.g., cars on a highway). (P3.4B)

3) Identify the force(s) acting on objects moving with uniform circular motion (e.g., a car on a circular track, satellites in orbit). Understand why uniform circular motion involves acceleration without a change in speed. (P3.4D, P2.2D)

P3.6 Gravitational Interactions

Gravitation is a universal attractive force that a mass exerts on every other mass. The strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.

Essential Learning Targets – Students will be able to:

1) Explain earth-moon interactions (orbital motion) in terms of forces. (P3.6A)
2) Predict how the gravitational force between objects changes when the distance between them changes. (P3.6B)
3) Explain how your weight on Earth could be different from your weight on another planet. (P3.6C)

Standard 4: Forms of Energy and Energy Transformations – Energy is a useful conceptual system for explaining how the universe works and accounting for changes in matter. Energy is not a "thing." Students develop several energy-related ideas: First, they keep track of energy during transfers and transformations, and account for changes using energy conservation. Second, they identify places where energy is apparently lost during a transformation process, but is actually spread around to the environment as thermal energy and therefore not easily recoverable. Third, they identify the means of energy transfers: collisions between particles, or waves.

P4.1 Energy Transfer

Moving objects and waves transfer energy from one location to another. They also transfer energy to objects during interactions (e.g., sunlight transfers energy to the ground when it warms the ground; sunlight also transfers energy from the Sun to the Earth).

Essential Learning Targets – Students will be able to:

1) Account for and represent energy into and out of systems using energy transfer diagrams. (P4.1A)
2) Explain instances of energy transfer by waves and objects in everyday activities (e.g., why the ground gets warm during the day, how you hear a distant sound, why it hurts when you are hit by a baseball). (P4.1B)

P4.2 Energy Transformation

Energy is often transformed from one form to another. The amount of energy before a transformation is equal to the amount of energy after the transformation. In most energy transformations, some energy is converted to thermal energy.

Essential Learning Targets – Students will be able to:

1) Name devices that transform specific types of energy into other types (e.g., a device that transforms electricity into motion). (P4.2B)

2) Explain how energy is conserved in common systems (e.g., light incident on a transparent material, light incident on a leaf, mechanical energy in a collision). Explain why (for example) all the stored energy in gasoline does not transform to mechanical energy of a vehicle. Explain why

all mechanical systems require an external energy source to maintain their motion. (P4.2C, P4.2D, P4.3C)

P4.4 Wave Characteristics

Waves (mechanical and electromagnetic) are described by their wavelength, amplitude, frequency, and speed.

Essential Learning Targets – Students will be able to:

1) Describe specific mechanical waves (e.g., on a demonstration spring, on the ocean) in terms of wavelength, amplitude, frequency, and speed. (P4.4A)
2) Identify everyday examples of transverse and compression (longitudinal) waves. Compare and contrast transverse and compression (longitudinal) waves in terms of wavelength, amplitude, and frequency. (P4.4B, P4.4C)

P4.5 Mechanical Wave Propagation

Vibrations in matter initiate mechanical waves (e.g., water waves, sound waves, seismic waves), which may propagate in all directions and decrease in intensity in proportion to the distance squared for a point source. Waves transfer energy from one place to another without transferring mass.

Essential Learning Targets – Students will be able to:

1) Identify everyday examples of energy transfer by waves and their sources. Explain why an object (e.g., fishing bobber) does not move forward as a wave passes under it. (P4.5A, P4.5B)
2) Provide evidence to support the claim that sound is energy transferred by a wave, not energy transferred by particles. (P4.5C)

P4.6 Electromagnetic Waves

Electromagnetic waves (e.g., radio, microwave, infrared, visible light, ultraviolet, x-ray) are produced by changing the motion (acceleration) of charges or by changing magnetic fields. Electromagnetic waves can travel through matter, but they do not require a material medium. (That is, they also travel through empty space.) All electromagnetic waves move in a vacuum at the speed of light. Types of electromagnetic radiation are distinguished from each other by their wavelength and energy.

Essential Learning Targets – Students will be able to:

1) Identify the different regions on the electromagnetic spectrum and compare them in terms of wavelength, frequency, and energy. (P4.6A)
2) Explain why radio waves can travel through space, but sound waves cannot. (P4.6B)
3) Explain why there is a delay between the time we send a radio message to astronauts on the moon and when they receive it. Explain why we see a distant event before we hear it (e.g., lightning before thunder, exploding fireworks before the boom). (P4.6C, P4.6D)

P4.10 Current Electricity – Circuits

Current electricity is described as movement of charges. It is a particularly useful form of energy because it can be easily transferred from place to place and readily transformed by various devices into other forms of energy (e.g., light, heat, sound, and motion). Electrical current (amperage) in a circuit is determined by the potential difference (voltage) of the power source and the resistance of the loads in the circuit.

Essential Learning Targets – Students will be able to:

1) Describe the energy transformations when electrical energy is produced and transferred to homes and businesses. (P4.10A)
2) Identify common household devices that transform electrical energy to other forms of energy, and describe the type of energy transformation. (P4.10B)
3) Given diagrams of many different possible connections of electric circuit elements, identify complete circuits, open circuits, and short circuits and explain the reasons for the classification. (P4.10C)
4) Discriminate between voltage, resistance, and current as they apply to an electric circuit. (P4.10D)

P4.12 Nuclear Reactions

Changes in atomic nuclei can occur through three processes: fission, fusion, and radioactive decay. Fission and fusion can convert small amounts of matter into large amounts of energy. Fission is the splitting of a large nucleus into smaller nuclei at extremely high temperature and pressure. Fusion is the combination of smaller nuclei into a large nucleus and is responsible for the energy of the Sun and other stars. Radioactive decay occurs naturally in the Earth's crust (rocks, minerals) and can be used in technological applications (e.g., medical diagnosis and treatment).

Essential Learning Targets – Students will be able to:

1) Describe peaceful technological applications of nuclear fission and radioactive decay. (P4.12A)
2) Describe possible problems caused by exposure to prolonged radioactive decay. (P4.12B)
3) Explain how stars, including our Sun, produce huge amounts of energy (e.g., visible, infrared, ultraviolet light). (P4.12C)