03 Work, Energy, and Power

Content Area:	**Science**
Course(s):	**AP Physics C**
Time Period:	**Semester 1**
Length:	**2 weeks**
Status:	**Published**

Standards

SCI.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.
	Using Mathematics and Computational Thinking
SCI.HS.PS3.B	Conservation of Energy and Energy Transfer
	Systems and System Models
SCI.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).
	Developing and Using Models
SCI.HS.PS3.A	Definitions of Energy
SCI.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.
	Constructing Explanations and Designing Solutions
SCI.HS.PS3.D	Energy in Chemical Processes
SCI.HS.ETS1.A	Defining and Delimiting Engineering Problems
	Energy and Matter
SCI.HS-ESS1-4	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

AP Physics C Learning Objectives

Note: Learning Objectives are taken verbatim from the AP Physics C - Mechanics Course and Exam Description. The verb "describe" could refer to a variety of different methods of expression (e.g. words, diagrams, graphs, mathematical expressions), as appropriate.

Describe the translational kinetic energy of an object in terms of the object’s mass and velocity.

Describe the work done on an object or system by a given force or collection of forces.

Describe the potential energy of a system.

Describe the energies present in a system.

Describe the behavior of a system using conservation of mechanical energy principles.

Describe how the selection of a system determines whether the energy of that system changes.

Describe the transfer of energy into, out of, or within a system in terms of power.

Enduring Understandings

Interactions produce changes in motion.

Forces characterize interactions between objects or systems.

Fields predict and describe interactions.

Conservation laws constrain interactions.

When a force is exerted on an object, and the energy of the object changes, then work was done on the object.

Conservative forces internal to a system can change the potential energy of that system.

The energy of a system can transform from one form to another without changing the total amount of energy in the system.

The energy of an object or a system can be changed at different rates.

Essential Questions

Does pushing an object always change its energy?
If energy is conserved, why are we running out of it?
How much money can you save by charging your phone at school instead of at home?
Why does a stretched rubber band return to its original length?
Why does it seem easier to carry a large box up a ramp rather than a set of stairs?

Knowledge and Skills

Topic 3.1 Translational Kinetic Energy
Knowledge:

- An object’s translational kinetic energy is given by the equation:
- Translational kinetic energy is a scalar quantity.
- Different observers may measure different values of the translational kinetic energy of an object, depending on the observer’s frame of reference.

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.

- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Topic 3.2 Work

Knowledge:

- Work is the amount of energy transferred into or out of a system by a force exerted on that system over a distance.
- The work done by a conservative force exerted on a system is path-independent and only depends on the initial and final configurations of that system.
- The work done by a conservative force on a system—or the change in the potential energy of the system—will be zero if the system returns to its initial configuration.
- Potential energies are associated only with conservative forces.
- The work done by a nonconservative force is path-dependent.
- The most common nonconservative forces are friction and air resistance.
- Work is a scalar quantity that may be positive, negative, or zero.
- The work done on an object by a variable force is calculated using where the integral is taken over the path from point a to point b.
- The dot product between two vectors, A and B, results in a scalar quantity of magnitude $A \cdot B = AB\cos\theta$.
- Only the component of the force exerted on a system that is parallel to the displacement of the point of application of the force will change the system's total energy.
- If the component of the force exerted on a system that is parallel to the displacement is constant, the work done on the system by the force is given by the derived equation $W = Fd = Fd\cos\theta$.
- The component of the force exerted on a system perpendicular to the direction of the displacement of the system's center of mass can change the direction of the system's motion without changing the system's kinetic energy.
- The work–energy theorem states that the change in an object's kinetic energy is equal to the sum of the work (net work) being done by all forces exerted on the object.
- An external force may change the configuration of a system. The component of the external force parallel to the displacement times the displacement of the point of application of the force gives the change in kinetic energy of the system.
- If the system's center of mass and the point of application of the force move the same distance when a force is exerted on a system, then the system may be modeled as an object, and only the system's kinetic energy can change.
- The energy dissipated by friction is typically equated to the force of friction times the length of the path over which the force is exerted.
- Work is equal to the area under the curve of a graph of $F_{\|}$ as a function of displacement.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 3.3 Potential Energy

Knowledge:

- A system composed of two or more objects has potential energy if the objects within that system only interact with each other through conservative forces.
- Potential energy is a scalar quantity associated with the position of objects within a system.
- The definition of zero potential energy for a given system is a decision made by the observer considering the situation to simplify or otherwise assist in analysis.
- The relationship between conservative forces exerted on a system and the system's potential energy is .
- The conservative forces exerted on a system in a single dimension can be determined using the slope of the system's potential energy with respect to position in that dimension; these forces point in the direction of decreasing potential energy.
- Graphs of a system's potential energy as a function of its position can be useful in determining physical properties of that system.
- Stable equilibrium is a location at which a small displacement in an object's position results in a force exerted on the object opposite to the direction of the small displacement, accelerating the object back toward the equilibrium position.
- Unstable equilibrium is a location at which a small displacement in an object's position results in a force exerted on the object in the same direction as the small displacement, accelerating the object away from the equilibrium position.
- In a given dimension, stable equilibrium positions exist at locations where the potential energy as a function of position in that dimension has a local minimum.
- In a given dimension, unstable equilibrium positions occur at locations where the potential energy as a function of position in that dimension has a local maximum.
- The potential energy of common physical systems can be described using the physical properties of that system.
- The elastic potential energy of an ideal spring is given by the following equation, where Δx is the distance the spring has been stretched or compressed from its equilibrium length.
- The general form for the gravitational potential energy of a system consisting of two approximately spherical distributions of mass (e.g., moons, planets, or stars) is given by the equation .
- Because the gravitational field near the surface of a planet is nearly constant, the change in gravitational potential energy in a system consisting of an object with mass m and a planet with gravitational field of magnitude g when the object is near the surface of the planet may be approximated by the equation $\Delta U_g = mg\Delta y$.

The total potential energy of a system containing more than two objects is the sum of the potential energy of each pair of objects within the system.

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 3.4 Conservation of Energy

Knowledge:

- A system composed of only a single object can only have kinetic energy.
- A system that contains objects that interact via conservative forces or that can change its shape reversibly may have both kinetic and potential energies.
- Mechanical energy is the sum of a system's kinetic and potential energies.
- Any change to a type of energy within a system must be balanced by an equivalent change of other types of energies within the system or by a transfer of energy between the system and its surroundings.
- A system may be selected so that the total energy of that system is constant.
- If the total energy of a system changes, that change will be equivalent to the energy transferred into or out of the system.
- Energy is conserved in all interactions.
- If the work done on a selected system is zero and there are no nonconservative interactions within the system, the total mechanical energy of the system is constant.
- If the work done on a selected system is nonzero, energy is transferred between the system and the environment.

Skills:

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Create experimental procedures that are appropriate for a given scientific question.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Topic 3.5 Power

Knowledge:

- Power is the rate at which energy changes with respect to time, either by transfer into or out of a system or by conversion from one type to another within a system.
- Average power is the amount of energy being transferred or converted, divided by the time it took for that transfer or conversion to occur.
- Because work is the change in energy of an object or system due to a force, average power is the total work done, divided by the time during which that work was done.
- The instantaneous power delivered to an object by a force is given by the equation .
- The instantaneous power delivered to an object by the component of a constant force parallel to the object's velocity can be described with the derived equation .

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Transfer Goals

In Unit 3, students will be introduced to the idea of conservation as a foundational principle of physics, along with the concept of work as the primary agent of change for energy. As in earlier units, students will once again utilize both familiar and new models and representations to analyze physical situations, now with force or energy as major components. Students will be encouraged to call upon their knowledge of content and skills in Units 1 and 2 to determine the most appropriate technique for approaching a problem and will be challenged to understand the limiting factors of each technique.

Assessments

https://docs.google.com/document/d/1wR7bQF-8AQoRrt0g4C3hKja0yjwDjC9_BiAmONWbTcI/edit?usp=sharing

Modifications

https://docs.google.com/document/d/1ODqaPP69YkcFiyG72fIT8XsUIe3K1VSG7nxuc4CpCec/edit?usp=sharing