03 Work, Energy, and Power

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **Semester 1**
Length: **18 Periods**
Status: **Published**

Standards

	Patterns
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.
HS-PS3	Energy
	Systems and System Models
	Energy and Matter
	Cause and Effect
	Structure and Function
	Scale, Proportion, and Quantity
HS-ESS2	Earth's Systems
HS-ESS2-6	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
HS-ESS3	Earth and Human Activity
ESS3.A	Natural Resources
HS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
	Stability and Change
HS-ESS3-5	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
ETS1.A	Delimiting Engineering Problems
ETS1.B	Developing Possible Solutions
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Enduring Understandings

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.

A force exerted on an object can change the kinetic energy of the object.

Interactions with other objects or systems can change the total energy of a system.

The energy of a system is conserved

Essential Questions

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

Knowledge and Skills

3.1 Translational Kinetic Energy

Knowledge

- An object's translational kinetic energy is given by the equation $K = \frac{1}{2}mv^2$
- 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 a physical system.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim

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.

- Examples of non conservative forces are friction and air resistance.

- Work is a scalar quantity that may be positive, negative, or zero.

- The amount of work done on a system by a constant force is related to the components of that force and the displacement of the point at which that force is exerted.

    - 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.

    - 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$\Delta E_{mech} = F_f d \cos\theta$

- Work is equal to the area under the curve of a graph of F|| as a function of displacement.

Skills

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational 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.
- Create experimental procedures that are appropriate for a given scientific question.

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 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 $U_g = -G\frac{m_1 m_2}{r}$
    - 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 a physical system.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.
- 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.

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 diagrams, tables, charts, or schematics to represent physical situations.
- 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 locations in a single scenario.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

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 the component of a constant force parallel to the object's velocity can be described with the derived equation. $P_{inst} = F_{\parallel} v = Fv\cos\theta$

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 locations in a single scenario.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
- Create experimental procedures that are appropriate for a given scientific question.

Transfer Goals

Patterns: Observed patterns in nature guide organization and classification and prompt questions about

relationships and causes underlying them.

Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Assessments

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

Modifications

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