03 Work, Energy, and Power

Content Area: **Science**
Course(s):
Time Period: **Semester 1**
Length: **4 weeks**
Status: **Published**

Standards

SCI.HS.ESS3.A	Natural Resources
SCI.HS.ETS1.A	Delimiting Engineering Problems
SCI.HS.ETS1.B	Developing Possible Solutions
SCI.HS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
SCI.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.
SCI.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.
SCI.HS-PS3	Energy
SCI.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.
	Scale, Proportion, and Quantity
	Patterns
	Stability and Change
	Structure and Function
	Systems and System Models
	Energy and Matter
	Cause and Effect

Enduring Understandings

Open and Closed Systems: Energy

1. 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.

Work and Mechanical Energy

1. A force exerted on an object can change the kinetic energy of the object.
2. Interactions with other objects or systems can change the total energy of a system.

Conservation of Energy, the Work-Energy Principle, and Power

1. The energy of a system is conserved

Essential Questions

1. How does pushing something give it energy?
2. How is energy exchanged and transformed within or between systems?
3. How does the choice of system influence how energy is stored or how work is done?
4. How does energy conservation allow the riders in the back car of a rollercoaster to have a thrilling ride?
5. How can the idea of potential energy be used to describe the work done to move celestial bodies?
6. How is energy transferred between objects or systems?
7. How does the law of conservation of energy govern the interactions between objects and systems?

Knowledge and Skills

Knowledge:

1. A system is an object or a collection of objects. The objects are treated as having no internal structure.
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
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
4. The placement of a 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.
5. 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.

    d. The kinetic energy of a rigid system may be translational, rotational, or a combination of both. The change in the rotational kinetic energy of a rigid system is the product of the angular displacement and the net torque.

6. The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples include gravitational potential energy, elastic potential energy, and kinetic energy. a. A rotating, rigid body may be considered to be a system and may have both translational and rotational kinetic energy. b. Although thermodynamics is not part of Physics 1, included is the idea that, during an inelastic collision, some of the mechanical energy dissipates as (converts to) thermal energy.

7. 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 forces 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.

8. Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.

9. A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy.

10. 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.

b. Changes in the internal structure can result in changes in potential energy. Examples include mass-spring oscillators and objects falling in a gravitational field.

c. The change in electric potential in a circuit is the change in potential energy per unit charge.

11. 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.

12. Energy can be transferred by an external force exerted on an object or a 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.

Skills :

1. Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations
2. 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.
3. Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease, or remain unchanged.
4. Use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether the kinetic energy of that object would increase, decrease, or remain unchanged.
5. 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.
6. Calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.
7. Predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system
8. 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.
9. 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.
10. Create 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.
11. 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.
12. Calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.
13. Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy
14. Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
15. Apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
16. Describe and make predictions about the internal energy of systems.
17. Calculate changes in kinetic energy and potential energy of a system using information from representations of that system.
18. Design an experiment and analyze data to determine how a force exerted on an object or system does work on the object or system as it moves through a distance.
19. Design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.
20. Predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.
21. Make claims about the interaction between a system and its environment in which the environment

exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).

22. Predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

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_BiAmONWbTcl/edit?usp=sharing

Modifications

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