Unit 4 Energy

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **November**
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Enduring Understandings

- 5.A: 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.
- 3.E: A force exerted on an object can change the kinetic energy of the object.
- 4.C: Interactions with other objects or systems can change the total energy of a system.
- 5.B: The energy of a system is conserved.

Essential Questions

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

Content

4.1 Open and Closed Systems: Energy

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

5.A.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.

5.A.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.

5.A.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.

4.2 Work and Mechanical Energy

3.E.1: 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.

  Relevant Equation:

  $\Delta E = W = F_{||}d$

- 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.

  Relevant Equations:

  $K = (1/2)mv^2$

  $\Delta E = W = F_{||}d = Fd(\cos\theta)$

4.C.1: 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.

  Relevant Equations:

  $K = (1/2)mv^2$

  $K = (1/2)I\omega^2$

  $\Delta U_g = mg\Delta y$

  $U_G = -(Gm_1m_2)/r$

  $Us = (1/2)kx^2$

4.C.2: 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.

  Relevant Equation:

  $W = F_{||}d$

- 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.

  Relevant Equation:

  $\Delta E = W = F_{||}d = Fd(\cos\theta)$

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

5.B.1: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.

Relevant Equation:

$K = (1/2)mv^2$

5.B.2: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. [Physics 1 includes mass-spring oscillators and simple pendulums. Physics 2 includes charged objects in electric fields and examining changes in internal energy with changes in configuration.]

5.B.3: 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.

Relevant Equations:

$T_p = 2\pi(\sqrt{(l/g)})$

$T_s = 2\pi(\sqrt{(m/k)})$

$U_s = (1/2)kx^2$

$\Delta U_g = mg\Delta y$

5.B.4: 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.

5.B.5: 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. [A piston filled with gas getting compressed or expanded is treated in Physics 2 as part of thermodynamics.]4

Relevant Equations:

$\Delta E = W = F_{||}d = Fd(\cos \theta)$

$P = \Delta E/\Delta t$

Vocabulary

Vocabulary

- System
- Isolated/Closed System
- Open System
- External Force
- Internal Force
- Conserved Quantities
- Environment
- Surroundings
- Interactions
- Transfer
- Transformation
- Work
- Energy
- Internal Energy
- Mechanical Energy
- Kinetic Energy
- Rotational Kinetic Energy
- Translational Kinetic Energy
- Gravitational Potential Energy
- Elastic Potential Energy
- Thermal Energy
- Displacement
- 0-meter reference level
- Law of Conservation of Energy
- Power

Skills

Enduring Understanding	Topic	Science Practices
5.A	4.1 Open and Closed Systems: Energy	• 6.4 The student can make • 7.2 The student can conn
3.E, 4.C	4.2 Work and Mechanical Energy	• 1.4 The student can use r • 2.1 The student can justif • 2.2 The student can apply • 6.4 The student can make • 7.2 The student can conn
5.B	4.3 Conservation of Energy, the Work-Energy Principle, and Power	• 1.4 The student can use r • 1.5 The student can re-ex • 2.1 The student can justif • 2.2 The student can apply

- 4.2 The student can desig
- 5.1 The student can analy
- 6.4 The student can make
- 7.2 The student can conn

Learning Objective (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

- Learning Objective (3.D.1.1): The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.
- Learning Objective (3.D.2.1): The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.
- Learning Objective (3.D.2.2): The student is able to predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Learning Objective (3.D.2.3): The student is able to analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Learning Objective (3.D.2.4): The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.
- Learning Objective (4.B.1.1): The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).
- Learning Objective (4.B.1.2): The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.
- Learning Objective (4.B.2.1): The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.
- Learning Objective (4.B.2.2): The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system.
- Learning Objective (5.A.2.1): The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
- Learning Objective (5.D.1.1): The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.
- Learning Objective (5.D.1.2): The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations.
- Learning Objective (5.D.1.3): The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.
- Learning Objective (5.D.1.4): The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically,

and evaluate the match between the prediction and the outcome.

- Learning Objective (5.D.1.5): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.
- Learning Objective (5.D.2.1): The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.
- Learning Objective (5.D.2.2): The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
- Learning Objective (5.D.2.3): The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
- Learning Objective (5.D.2.4): The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force.
- Learning Objective (5.D.2.5): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.
- Learning Objective (5.D.3.1): The student is able to predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force).

Standards

AP: Physics 1 (2021 - 2022)

Big Idea 3: The interactions of an object with other objects can be described by forces.

- Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.
    - Learning Objective (3.E.1.1): 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. [See Science Practices 6.4 and 7.2]
    - Learning Objective (3.E.1.2): Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease, or remain unchanged. [See Science Practice 1.4]
    - Learning Objective (3.E.1.3): 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. [See Science Practices 1.4 and 2.2]
    - Learning Objective (3.E.1.4): 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. [See Science Practice 2.2]

Big Idea 4: Interactions between systems can result in changes in those systems.

- Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.
    - Learning Objective (4.C.1.1): 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. [See Science Practices 1.4, 2.1, and 2.2]
    - Learning Objective (4.C.1.2): Predict changes in the total energy of a system due to changes in position and speed

of objects or frictional interactions within the system. [See Science Practice 6.4]
    - Learning Objective (4.C.2.1): 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. [See Science Practice 6.4]
    - Learning Objective (4.C.2.2): 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. [See Science Practices 1.4, 2.2, and 7.2]

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

- Enduring Understanding 5.A: 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.
    - Learning Objective (5.A.2.1): The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [See Science Practices 6.4 and 7.2]

- Enduring Understanding 5.B: The energy of a system is conserved.
    - Learning Objective (5.B.1.1): 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. [See Science Practices 1.4 and 2.2]
    - Learning Objective (5.B.1.2): 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. [See Science Practice 1.5]
    - Learning Objective (5.B.2.1): 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. [See Science Practices 1.4 and 2.1]
    - Learning Objective (5.B.3.1): Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. [See Science Practices 2.2, 6.4, and 7.2]
    - Learning Objective (5.B.3.2): Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. [See Science Practices 1.4 and 2.2]
    - Learning Objective (5.B.3.3): 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. [See Science Practices 1.4 and2.2]
    - Learning Objective (5.B.4.1): Describe and make predictions about the internal energy of systems. [See Science Practices 6.4 and 7.2]
    - Learning Objective (5.B.4.2): Calculate changes in kinetic energy and potential energy of a system using information from representations of that system. [See Science Practices 1.4, 2.1, and 2.2]
    - Learning Objective (5.B.5.1): 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. [See Science Practices 4.2 and 5.1]
    - Learning Objective (5.B.5.2): 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. [See Science Practices 4.2 and 5.1]
    - Learning Objective (5.B.5.3): 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. [See Science Practices 1.4, 2.2, and 6.4]
    - Learning Objective (5.B.5.4): 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). [See Science Practices 6.4 and 7.2]
    - Learning Objective (5.B.5.5): 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. [See Science Practices 2.2 and 6.4]

Resources