Grade 8 Science, Unit 5

Relationships Among Forms of Energy

Overview

Unit abstract

Upon completion of this unit of study, students will understand the relationship between energy and forces. Students develop their understanding of important qualitative ideas about energy, including that the interactions of objects can be explained and predicted using the concept of transfer of energy from one object or system of objects to another, and the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students understand that objects that are moving have kinetic energy and that objects may also contain stored (potential) energy, depending on their relative positions. Students will also begin to know the difference between energy and temperature, and the relationship between forces and energy. Students will use the practices of analyzing and interpreting data, developing and using models, and engaging in argument from evidence. The crosscutting concepts of scale, proportion, and quantity; systems and system models; and energy and matter will support understanding across this unit of study.

Essential question

How can energy be transferred from one object or system to another?

Written Curriculum

Next Generation Science Standards

MS. Energy

Students who demonstrate understanding can:

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. ▪ Construct and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-1)	**PS3.A: Definitions of Energy** ▪ Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)	**Scale, Proportion, and Quantity** ▪ Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1)

Connections to other DCIs in this grade-band: **MS.PS2.A** (MS-PS3-1)

Articulation across grade-bands: **4.PS3.B** (MS-PS3-1); **HS.PS3.A** (MS-PS3-1); **HS.PS3.B** (MS-PS3-1)

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS3-1)*

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS3-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. (MS-PS3-1)

6.RP.A.1 Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS3-1)

6.RP.A.2 Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship. *(MS-PS3-1)*

7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-PS3-1)

8.EE.A.1 Know and apply the properties of integer exponents to generate equivalent numerical expressions. (MS-PS3-1)

8.EE.A.2 Use square root and cube root symbols to represent solutions to equations of the form x2 = p and x3 = p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. *(MS-PS3-1)*

8.F.A.3 Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS3-1)

MS. Energy		
Students who demonstrate understanding can: **MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]		
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices **Developing and Using Models** Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. ▪ Develop a model to describe unobservable mechanisms. (MS-PS3-2)	**Disciplinary Core Ideas** **PS3.A: Definitions of Energy** ▪ A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) **PS3.C: Relationship Between Energy and Forces** ▪ When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)	**Crosscutting Concepts** **Systems and System Models** ▪ Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)
Connections to other DCIs in this grade-band: N/A		
Articulation across grade-bands: **HS.PS2.B** (MS-PS3-2); **HS.PS3.B** (MS-PS3-2); **HS.PS3.C** (MS-PS3-2)		
Common Core State Standards Connections: *ELA/Literacy –* **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-PS3-2)*		

MS. Energy

Students who demonstrate understanding can:

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds. ▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. (MS-PS3-5) -- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-5)	**PS3.B: Conservation of Energy and Energy Transfer** ▪ When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)	**Energy and Matter** ▪ Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5)

Connections to other DCIs in this grade-band: **MS.PS2.A** (MS-PS3-5)

Articulation across grade-bands: **4.PS3.C** (MS-PS3-5); **HS.PS3.A** (MS-PS3-5); **HS.PS3.B** (MS-PS3-5)

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS3-5)*

WHST.6-8.1 Write arguments focused on discipline content. *(MS-PS3-5)*

Mathematics –

MP.2 Reason abstractly and quantitatively. (MS-PS3-5)

6.RP.A.1 Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. *(MS-PS3-5)*

7.RP.A.2 Recognize and represent proportional relationships between quantities. *(MS-PS3-5)*

8.F.A.3 Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. *(MS-PS3-5)*

Clarifying the standards

Prior learning

The following disciplinary core ideas are prior learning for the concepts in this unit of study. By the end of Grade 5, students know that:

- Energy is present whenever there are moving objects, sound, light, or heat.
- When objects collide, energy can be transferred from one object to another, thereby changing the objects' motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- Light also transfers energy from place to place.
- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light.
- Transforming the energy of motion into electrical energy may have produced currents.
- When objects collide, the contact forces the transfer of energy so as to change the objects' motions.

Progression of current learning

<table>
<tr><th colspan="2">Driving question 1
How can the relationships of kinetic energy to the mass of an object and to the speed of an object be described?</th></tr>
<tr><td>Concepts
Kinetic energy is related to the mass of an object and to the speed of an object.
Kinetic energy has a relationship to mass separate from its relationship to speed.
Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of the object's speed.
Proportional relationships among different types of quantities provide information about the magnitude of properties and processes.</td><td>Practices
Construct and interpret graphical displays of data to identify linear and nonlinear relationships of kinetic energy to the mass of an object and to the speed of an object.</td></tr>
</table>

Driving question 2
What happens to the amount of potential energy stored in the system when the arrangement of objects interacting at a distance changes?

<table>
<tr><th>Concepts</th><th>Practices</th></tr>
<tr><td>
When the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
A system of objects may contain stored (potential) energy, depending on the objects' relative positions.
When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the objects.
Models that could include representations, diagrams, pictures, and written descriptions of systems can be used to represent systems and their interactions, such as inputs, processes, and outputs, and energy and matter flows within systems.
</td><td>
Develop a model to describe what happens to the amount of potential energy stored in the system when the arrangement of objects interacting at a distance changes
Use models to represent systems and their interactions, such as inputs, processes, andoutputs, and energy and matter flows within systems. Models could include representations, diagrams, pictures, and written descriptions.
</td></tr>
</table>

Driving question 3
How can arguments be constructed, used and presented to support the claim that when the kinetic energy of an object changes, the energy is transferred to or from the object?

<table>
<tr><th>Concepts</th><th>Practices</th></tr>
<tr><td>
When the kinetic energy of an object changes, energy is transferred to or from the object.
When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
Kinetic energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).
</td><td>
Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
Conduct an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object. Do not include calculations of energy.
</td></tr>
</table>

<u>Integration of content, practices, and crosscutting concepts</u>

Prior to middle school, students know that energy is present whenever there are moving objects, sound, light, or heat and that when objects collide, energy can be transferred from one object to another, thereby changing the objects' motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Students also know that when objects collide, the contact forces transfer energy so as to change the objects' motions.

Students will need to construct graphical displays of data that describe the relationships between kinetic energy and mass of an object and speed of an object. These displays can be based on information from examples such as riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a whiffle ball versus a tennis ball. Through using one of these examples, students can record either mass or speed data to identify linear and nonlinear relationships. When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, students will use square root and cube root symbols to represent solutions to equations of the form x2=p and x3=p, where p is a positive rational number. A simple demonstration of how increased speed or mass contributes to increased kinetic energy could include two objects of different masses (e.g., balls) rolling into a targets (e.g., plastic bowling pins, wooden blocks, etc). From these examples, students will also be able to describe differences between kinetic energy and mass separately from kinetic energy and speed. Students will understand that an increase in speed will have a different effect on kinetic energy than an increase in mass. They will recognize and represent proportional relationships between kinetic energy and mass separately from kinetic energy and speed. Students will include a narrative that explains the information found in their graphical displays.

Students investigate the potential energy stored in a variety of systems. It will be necessary for students to have opportunities to rearrange objects in the systems in order to determine the impact on the amount of potential energy stored in the system. Systems to be investigated could be balloons with static electrical charge being brought closer to a classmate's hair, carts at varying positions on a hill, cars at different positions on hot wheels tracks, objects at varying heights on shelves (drop a book of the same mass from different heights onto a cup) to demonstrate changes to potential energy in a system. Students will develop models to describe how changing distance changes the amount of potential energy stored in the system. The models students use to describe any of these examples will be multimedia presentations that could include diagrams, pictures, and/or written descriptions of the system examined. These models will help students represent interactions within systems, such as inputs, processes, and outputs, and energy flows within the system.

Students will now have an opportunity to use an understanding of kinetic and potential energy within a system to construct a claim about the relationship between the transfer of energy to or from an object and changes in kinetic energy. Using data from the graphical displays of data and models that students developed earlier in this unit of study, as well as textual evidence, students will construct, use, and present oral and written arguments to support claims that when kinetic energy changes, energy is transferred to or from the object. Students can provide evidence of this energy transfer by looking at the distance an object travels when energy is transferred, how temperature changes when energy is transferred, or how a compass responds to a magnetic field at different distances. Students will conduct an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object, but they are not required to include calculations of energy. However, students should interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line and be able to give examples of functions that are not linear when describing the change in the kinetic energy of an object and the energy transferred to or from the object.

Integration of mathematics and/or English language arts/literacy

Mathematics

Reason abstractly and quantitatively by interpreting numerical, graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Describe a ratio relationship between kinetic energy and mass separately from kinetic energy and speed.

Understand the concept of a unit rate a/b associated with a ratio a:b with b≠, and use rate language in the context of a ratio relationship *between kinetic energy and mass separately from kinetic energy and speed.*

Recognize and represent proportional relationships between kinetic energy and mass separately from kinetic energy and speed.

Know and apply the properties of integer exponents to generate equivalent numerical expressions when describing the relationships between kinetic energy and mass separately from kinetic energy and speed.

When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, use square root and cube root symbols to represent solutions to equations of the form x2=p and x3=p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that $\sqrt{2}$ is irrational.

When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line; give examples of functions that are not linear.

Reason abstractly and quantitatively when analyzing data to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Understand the concept of ratio and use ratio language to describe the ratio relationships between *the change in the kinetic energy of an object and the energy transferred to or from the object.*

Recognize and represent proportional relationships between the change in the kinetic energy of an object and the energy transferred to or from the object.

Interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line; give examples of functions that are not linear *when describing the change in the kinetic energy of an object and the energy transferred to or from the object.*

English language arts/literacy

Cite specific textual evidence to support analysis of science and technical *texts that describe the relationships of kinetic energy to the mass of an object and to the speed of an object*, attending to the precise details of explanations or descriptions.

Integrate quantitative or technical *information that describes the relationship of kinetic energy to the mass of an object and to the speed of object* that is expressed in words with a version of that information expressed visually in a flowchart, diagram, model, graph, or table.

Integrate multimedia and visual displays into presentations *that describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy* are stored in the system to clarify information, strengthen claims and evidence, and add interest.

Cite specific textual evidence to support analysis of science and technical texts *to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object,* attending to the precise details of explanations or descriptions.

Write arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Future learning

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles).

In some cases, the relative position of energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

The availability of energy limits what can occur in any system.

Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.

Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Number of Instructional Days

Recommended number of instructional days: 22 (1 day = approximately 50 minutes)

Note—The recommended number of days is an estimate based on the information available at this time. Teachers are strongly encouraged to review the entire unit of study carefully and collaboratively to determine whether adjustments to this estimate need to be made.