MS-PS3-1 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 expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

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.

Observable features of the student performance by the end of the course:

1	Organizing data		
	a	Students use graphical displays to organize the following given data:	
		i.	Mass of the object.
		ii.	Speed of the object.
		iii.	Kinetic energy of the object.
	b	Students organize the data in a way that facilitates analysis and interpretation.	
2	Identifying relationships		
	a	Using the graphical display, students identify that kinetic energy:	
		i.	Increases if either the mass or the speed of the object increases or if both increase.
		ii.	Decreases if either the mass or the speed of the object decreases or if both decrease.
3	Interpreting data		
	a	Using the analyzed data, students describe*:	
		i.	The relationship between kinetic energy and mass as a linear proportional relationship (KE ∝ m) in which:
			1. The kinetic energy doubles as the mass of the object doubles.
			2. The kinetic energy halves as the mass of the object halves.
		ii.	The relationship between kinetic energy and speed as a nonlinear (square) proportional relationship (KE ∝ v2) in which:
			1. The kinetic energy quadruples as the speed of the object doubles.
			2. The kinetic energy decreases by a factor of four as the speed of the object is cut in half.

MS-PS3-2 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 expectation above was 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.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- A system of objects may also contain stored (potential) energy, depending on their relative positions.

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.

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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon involving two objects interacting at a distance, students develop a model in which they identify the relevant components, including:	
		i.	A system of two stationary objects that interact.
		ii.	Forces (electric, magnetic, or gravitational) through which the two objects interact.
		iii.	Distance between the two objects.
		iv.	Potential energy.
2	Relationships		
	a	In the model, students identify and describe* relationships between components, including:	
		i.	When two objects interact at a distance, each one exerts a force on the other that can cause energy to be transferred to or from an object.
		ii.	As the relative position of two objects (neutral, charged, magnetic) changes, the potential energy of the system (associated with interactions via electric, magnetic, and gravitational forces) changes (e.g., when a ball is raised, energy is stored in the gravitational interaction between the Earth and the ball).
3	Connections		
	a	Students use the model to provide a causal account for the idea that the amount of potential energy in a system of objects changes when the distance between stationary objects interacting in the system changes because:	
		i.	A force has to be applied to move two attracting objects farther apart, transferring energy to the system.
		ii.	A force has to be applied to move two repelling objects closer together, transferring energy to the system.

MS-PS3-3 Energy

Students who demonstrate understanding can:

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.*(secondary)*

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. *(secondary)*

Crosscutting Concepts

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve that requires either minimizing or maximizing thermal energy transfer, students design and build a solution to the problem. In the designs, students:	
		i.	Identify that thermal energy is transferred from hotter objects to colder objects.
		ii.	Describe* different types of materials used in the design solution and their properties (e.g., thickness, heat conductivity, reflectivity) and how these materials will be used to minimize or maximize thermal energy transfer.
		iii.	Specify how the device will solve the problem.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria and constraints that will be taken into account in the design solution:	
		i.	Students describe* criteria, including:

		1. The minimum or maximum temperature difference that the device is required to maintain.
		2. The amount of time that the device is required to maintain this difference.
		3. Whether the device is intended to maximize or minimize the transfer of thermal energy.
		ii. Students describe* constraints, which may include:
		1. Materials.
		2. Safety.
		3. Time.
		4. Cost.
3	Evaluating potential solutions	
	a	Students test the device to determine its ability to maximize or minimize the flow of thermal energy, using the rate of temperature change as a measure of success.
	b	Students use their knowledge of thermal energy transfer and the results of the testing to evaluate the design systematically against the criteria and constraints.

MS-PS3-4 Energy

Students who demonstrate understanding can:

MS-PS3-4. **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

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

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

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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

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

Crosscutting Concepts

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.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon under investigation		
	a	Students identify the phenomenon under investigation involving thermal energy transfer.	
	b	Students describe* the purpose of the investigation, including determining the relationships among the following factors:	
		i.	The transfer of thermal energy.
		ii.	The type of matter.
		iii.	The mass of the matter involved in thermal energy transfer.
		iv.	The change in the average kinetic energy of the particles.
2	Identifying the evidence to address the purpose of the investigation		
	a	Individually or collaboratively, students develop an investigation plan that describes* the data to be collected and the evidence to be derived from the data, including:	
		i.	That the following data are to be collected:
			1. Initial and final temperatures of the materials used in the investigation.
			2. Types of matter used in the investigation.
			3. Mass of matter used in the investigation.
		ii.	How the collected data will be used to:

		1.	Provide evidence of proportional relationships between changes in temperature of materials and the mass of those materials.
		2.	Relate the changes in temperature in the sample to the types of matter and to the change in the average kinetic energy of the particles.
3	Planning the investigation		
	a	In the investigation plan, students describe*:	
		i.	How the mass of the materials are to be measured and in what units.
		ii.	How and when the temperatures of the materials are to be measured and in what units.
		iii.	Details of the experimental conditions that will allow the appropriate data to be collected to address the purpose of the investigation (e.g., time between temperature measurements, amounts of sample used, types of materials used), including appropriate independent and dependent variables and controls.

MS-PS3-5 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 expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

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.

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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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Energy and Matter

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

Observable features of the student performance by the end of the course:			
1	Supported claims		
	a	Students make a claim about a given explanation or model for a phenomenon. In their claim, students include idea that when the kinetic energy of an object changes, energy is transferred to or from that object.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including the following when appropriate:	
		i.	The change in observable features (e.g., motion, temperature, sound) of an object before and after the interaction that changes the kinetic energy of the object.
		ii.	The change in observable features of other objects or the surroundings in the defined system.
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the necessary and sufficient evidence and construct the argument. Students describe* a chain of reasoning that includes:	
		i.	Based on changes in the observable features of the object (e.g., motion, temperature), the kinetic energy of the object changed.
		ii.	When the kinetic energy of the object increases or decreases, the energy (e.g., kinetic, thermal, potential) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or from the object.
	b	Students present oral or written arguments to support or refute the given explanation or model for the phenomenon.	