Summative Assessments

Science Practice Test Teacher Guide

NM-ASR

High School

COGNIA ASSESSMENTS

Table of Contents

Practice Test Items

Session 1: Items 1–12

Item 1: Standalone Item

Next Generation Science Standards Description

PE: HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

SEP: Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

DCI: ESS2.C: The Roles of Water in Earth's Surface Processes: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

CCC: Structure and Function: The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low | CCC-Med

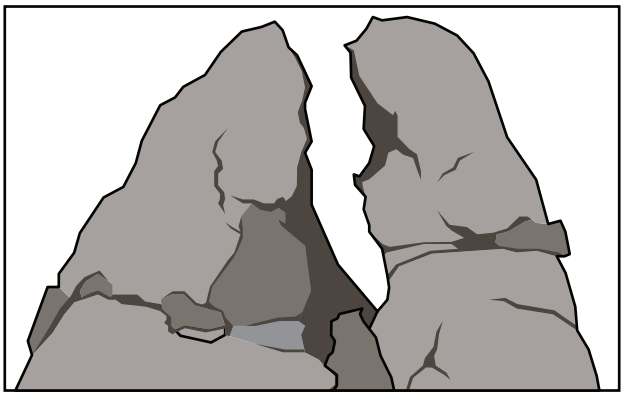
Number of Points: 2

Item on next page

This item brings students into the story line by asking them to plan an investigation of the properties of water and its effects on rocks during the natural process of freezing. The item aligns to the SEP by asking the students to plan an investigation that produces data that can be evidence that water can break rocks. The item aligns to the DCI because students must use knowledge of water's capacity to expand upon freezing. The item aligns to the CCC because students must use understanding of properties of rocks and water to plan their investigation.

A student who is hiking on a high mountain sees the large rock shown in the diagram.

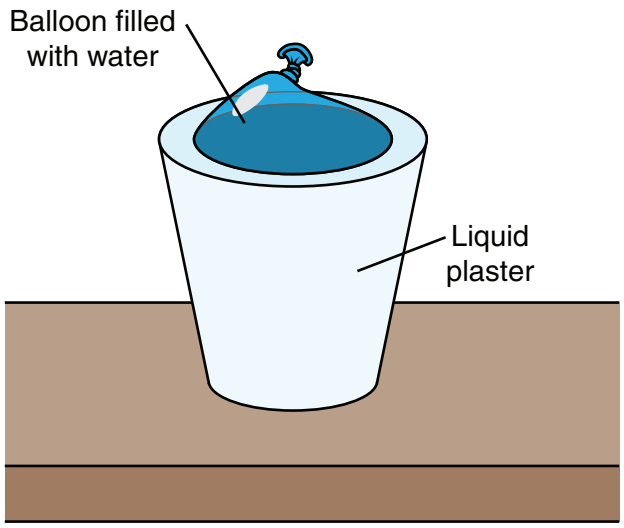
Mountain Rock



She wonders whether water could have caused the rock to break. To investigate, she mixes water with plaster in a paper cup. Then she fills a balloon with water and pushes the balloon into the liquid plaster in the cup. The next morning, the plaster has become solid like a rock and she peels away the paper cup.

The balloon is surrounded by plaster as shown in the diagram.

Plaster Rock



The stimulus for this item begins by presenting the phenomenon that water can cause rocks to break. The hook is that a student sees a large, cracked rock on a mountain. The phenomenon and hook are grade-level appropriate because many students have seen broken rocks.

This question has two parts. Be sure to answer both parts of the question.

1. **Part a**

Based on the diagrams, which action could the student take to collect data about whether water can break the plaster rock like the mountain rock?

A Put the plaster rock under running water so that water can erode the rock.

B Put the plaster rock in a bucket of water so that water can dissolve the rock.

C Put the plaster rock in an oven so that water can evaporate inside the balloon.

D Put the plaster rock in the freezer so that water can expand inside the balloon.

Part a is aligned to the SEP, DCI, and CCC. Students plan an investigation to collect data about whether water can break rocks by using their content knowledge that water expands upon freezing and their understanding of properties of rocks and water.

Part b

How could the investigation in Part (a) provide evidence of the natural process that caused changes in the mountain rock?

A When water freezes inside the balloon, the volume of the water increases, which applies pressure that cracks the plaster rock.

B When water evaporates inside the balloon, the volume of the water decreases, which applies pressure that cracks the plaster rock.

C When water flows over the plaster rock, water flows into cracks in the rock, which applies pressure that erodes small pieces of the rock.

D When water surrounds the plaster rock, water flows into the cracks in the rock, which applies pressure that dissolves the rock into small pieces.

Part b is aligned to the SEP, DCI, and CCC. Students describe how data from their investigation provide evidence of the natural process that breaks mountain rocks by using their content knowledge that water expands upon freezing and their understanding of properties of rocks and water.

Scoring Key

Part a
Correct Response: D

Part b
Correct Response: A

Distractor Rationales

Part a

A Erosion caused by water would wear away the mountain rock, not cause large breaks in the rock.

B Water does not dissolve rock.

C Evaporating water would not cause large breaks in the mountain rock.

D KEY: Cracks in the plaster caused by the expansion of water as water freezes would show how large breaks form in the mountain rock.

Part b

A KEY: As water freezes and expands inside cracks, the water takes up more space which causes pressure that can crack the rock.

B Evaporation would decrease, not increase, the volume of water in the rock and would not crack the rock.

C When water flows into cracks, pressure will not be applied unless the water freezes.

D Liquid water does not apply pressure to the rock.

Item 2: Standalone Item

Next Generation Science Standards Description

PE: HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to describe explanations.

DCI: PS2.B: Types of Interactions: 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.

CCC: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Item Type: Multiple Choice–Inline Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use the mathematical representation of Newton's law of gravitation to describe the gravitational force between two objects. The item aligns to the SEP by asking students to use the mathematical equation that represents gravitational force to describe gravitational interactions between the objects. The item aligns to the DCI because students must use knowledge of Newton's law of gravitation to describe the gravitational forces between objects. The item aligns to the CCC because students must use patterns in changes in mass and distance in their descriptions of the forces.

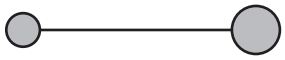
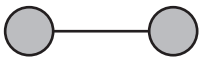
A student learns that one goal of space exploration is to launch rockets that can safely return to Earth and be reused. This involves careful calculations of the gravitational force between Earth and the rocket. The student learns that the gravitational force between two objects depends on the relationships and variables shown in the table.

Gravitational Force Equation

$F = G\frac{m_1 m_2}{d^2}$	F = Gravitational force G = Universal gravitational constant m_1 = Mass of object 1 m_2 = Mass of object 2 d = Distance between object 1 and object 2

The student uses three models to show how changes in mass and distance affect the gravitational force between a rocket and Earth. The table shows the masses and distances of objects in the models.

Three Gravitational Force Models

Model	Diagram
1	d = 10 meters  m_1 = 10 kilograms m_2 = 10 kilograms
2	d = 10 meters  m_1 = 5 kilograms m_2 = 10 kilograms
3	d = 5 meters  m_1 = 10 kilograms m_2 = 10 kilograms

The stimulus for this item begins by presenting the phenomenon that space exploration depends on calculating the gravitational force between a rocket and Earth. The hook is that a student learns that rockets that safely return to Earth can be reused. The phenomenon and hook are grade-level appropriate because many students are interested in rockets and hear about rocket launches in the news.

This question has two parts. Be sure to answer both parts of the question.

2. **Part a**

Which description of the gravitational force in the models is supported by the equation?

A The gravitational force between the objects in Model 2 is one-fifth the gravitational force between the objects in Model 1.

B The gravitational force between the objects in Model 2 is one-half the gravitational force between the objects in Model 1.

C The gravitational force between the objects in Model 2 is twice the gravitational force between the objects in Model 1.

D The gravitational force between the objects in Model 2 is five times the gravitational force between the objects in Model 1.

Part a is aligned to the SEP, DCI, and CCC. Students use the mathematical equation for gravitational force and their content knowledge that the equation describes the gravitational force between two objects to describe the pattern of change in gravitational force caused by changing the distance between the objects.

Part b

Use the equation to select the words that describe the gravitational force in the models.

The gravitational force between the objects in Model 3 is [one-fourth, one-half, twice, four times] the gravitational force between the objects in Model 1.

Part b is aligned to the SEP, DCI, and CCC. Students use the mathematical equation for gravitational force and their content knowledge that the equation describes the gravitational force between two objects to describe the pattern of change in gravitational force caused by changing the masses of the objects.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response:
The gravitational force between the objects in Model 3 is [one-fourth, one-half, twice, **four times**] the gravitational force between the objects in Model 1.

Distractor Rationales

Part a
A Students may be thinking about the 5 fewer kilograms in Model 2 than in Model 1, but the equation shows that force is proportional to the product of masses, not the number of kilograms.

B KEY: The equation shows that force is proportional to the product of the masses and the product of the masses in Model 2 is half the product of the masses in Model 1.

C The equation shows that force is directly, not inversely, proportional to the product of the masses. Less mass (in Model 2) does not cause more gravitational force.

D The product of the masses in Model 2 (5 kilograms x 10 kilograms) is half, not five times, the product of the masses in Model 1 (10 kilograms x 10 kilograms).

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 2: PBT Standalone Item

Next Generation Science Standards Description

PE: HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to describe explanations.

DCI: PS2.B: Types of Interactions: 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.

CCC: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use the mathematical representation of Newton's law of gravitation to describe the gravitational force between two objects. The item aligns to the SEP by asking students to use the mathematical equation that represents gravitational force to describe gravitational interactions between the objects. The item aligns to the DCI because students must use knowledge of Newton's law of gravitation to describe the gravitational forces between objects. The item aligns to the CCC because students must use patterns in changes in mass and distance in their descriptions of the forces.

A student learns that one goal of space exploration is to launch rockets that can safely return to Earth and be reused. This involves careful calculations of the gravitational force between Earth and the rocket. The student learns that the gravitational force between two objects depends on the relationships and variables shown in the table.

Gravitational Force Equation

$F = G\frac{m_1 m_2}{d^2}$	F = Gravitational force G = Universal gravitational constant m_1 = Mass of object 1 m_2 = Mass of object 2 d = Distance between object 1 and object 2

The student uses three models to show how changes in mass and distance affect the gravitational force between a rocket and Earth. The table shows the masses and distances of objects in the models.

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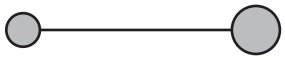
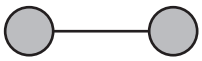
2	d = 10 meters  m_1 = 5 kilograms m_2 = 10 kilograms
3	d = 5 meters  m_1 = 10 kilograms m_2 = 10 kilograms

The stimulus for this item begins by presenting the phenomenon that space exploration depends on calculating the gravitational force between a rocket and Earth. The hook is that a student learns that rockets that safely return to Earth can be reused. The phenomenon and hook are grade-level appropriate because many students are interested in rockets and hear about rocket launches in the news.

This question has two parts. Be sure to answer both parts of the question.

2. **Part a**

Which description of the gravitational force in the models is supported by the equation?

A The gravitational force between the objects in Model 2 is one-fifth the gravitational force between the objects in Model 1.

B The gravitational force between the objects in Model 2 is one-half the gravitational force between the objects in Model 1.

C The gravitational force between the objects in Model 2 is twice the gravitational force between the objects in Model 1.

D The gravitational force between the objects in Model 2 is five times the gravitational force between the objects in Model 1.

Part a is aligned to the SEP, DCI, and CCC. Students use the mathematical equation for gravitational force and their content knowledge that the equation describes the gravitational force between two objects to describe the pattern of change in gravitational force caused by changing the distance between the objects.

Part b

Which statement describes the gravitational force in the models?

A The gravitational force between the objects in Model 3 is one-fourth the gravitational force between the objects in Model 1.

B The gravitational force between the objects in Model 3 is one-half the gravitational force between the objects in Model 1.

C The gravitational force between the objects in Model 3 is twice the gravitational force between the objects in Model 1.

D The gravitational force between the objects in Model 3 is four times the gravitational force between the objects in Model 1.

Part b is aligned to the SEP, DCI, and CCC. Students use the mathematical equation for gravitational force and their content knowledge that the equation describes the gravitational force between two objects to describe the pattern of change in gravitational force caused by changing the masses of the objects.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: D

Distractor Rationales

Part a

A Students may think that there are 5 fewer kilograms in Model 2 than in Model 1, but the force is proportional to the product of masses, not the number of kilograms.

B KEY: The equation shows that force is proportional to the product of the masses and the product of the masses in Model 2 is half the product of the masses in Model 1.

C The equation shows that force is directly, not inversely, proportional to the product of the masses. Less mass (in Model 2) does not cause more gravitational force.

D The product of the masses in Model 2 (5 kilograms x 10 kilograms) is half, not one-fifth, the product of the masses in Model 1 (10 kilograms x 10 kilograms).

Part b

A The equation shows that half the distance would result in 4 times more force, not one-fourth as much force.

B The equation shows that force is inversely proportional to the square of distance, not proportional to distance. Less distance (in Model 3) causes more, not less, gravitational force.

C The equation shows that force is inversely proportional to the square of distance, not inversely proportional to distance.

D KEY: The equation shows that force is inversely proportional to the square of distance, so the force in Model 3 (at half the distance) is four times the force of Model 1.

Item 3: Standalone Item

Next Generation Science Standards Description

PE: HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Asking Questions and Defining Problems: Ask questions that arise from examining models or a theory to clarify relationships.

DCI: LS3.A: Inheritance of Traits: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Low

Number of Points: 2

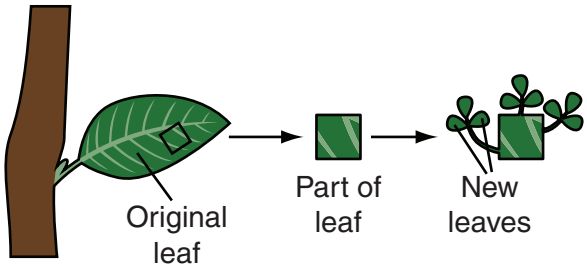
Item on next page

This item brings students into the story line by having them ask questions to clarify relationships about the role of chromosomes in coding for the traits in specialized cells in a plant leaf. The item aligns to the SEP by asking students to identify questions that clarify relationships between chromosomes and leaf cell structures and functions. The item aligns to the DCI because students must use knowledge that chromosomes contain the instructions for leaf characteristics. The item aligns to the CCC because students must use evidence to make a claim about cause and effect relationships between chromosomes, specialized cell structures, and cell functions.

A student learns that multicellular organisms have different types of specialized cells, but each somatic cell in the organism has the same number of chromosomes. For example, leaves have specialized cells for transporting water and gases through the leaf.

She reads about an investigation that scientists designed in order to study specialized cells in leaves. Scientists put part of a leaf into a solution with hormone and nutrient. In a few days, new leaves were observed growing on the original leaf. The diagram shows the original leaf and the new leaves.

Growing New Leaves



The stimulus for this item begins by presenting the phenomenon that multicellular organisms have different specialized cells even though all the cells have the same number of chromosomes. The hook is that a student reads about an investigation in which scientists grew a new leaf from part of a leaf. The phenomenon and hook are grade-level appropriate because many students are familiar with specialized cells and some may have used hormones and nutrients to help plants grow.

This question has two parts. Be sure to answer both parts of the question.

3. **Part a**

Which question could be answered by the investigation shown in the diagram?

A What process causes cells with the same chromosomes to produce specialized cell structures?

B What process causes some chromosomes to divide and produce new chromosomes and specialized cell structures?

C What process causes some chromosomes to produce more specialized cells than other chromosomes?

D What process causes cells with the same chromosomes to mutate and produce specialized cells?

Part a is aligned to the SEP, DCI, and CCC. Students choose a question that clarifies the relationship between chromosomes and leaf cell structures by using their content knowledge that chromosomes contain the instructions for leaf characteristics and the cause and effect relationship between chromosomes and specialized cell structures.

Part b

The scientists compared cells in the original leaf to cells in the new leaves.

Which question could this comparison answer?

A How do the chromosomes in leaves help the plant transport water and gases?

B Do chromosomes transport water and gases in the original leaf and the new leaves?

C How many chromosomes do the leaves use to build structures that transport water and gases?

D Which parts of the chromosomes in leaves contain instructions for cell structures that transport water and gases?

Part b is aligned to the SEP, DCI, and CCC. Students choose a question that clarifies the relationship between chromosomes and leaf cell functions by using their content knowledge that chromosomes contain the instructions for leaf characteristics and the cause and effect relationship between chromosomes and the functions of specialized cells.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: D

Distractor Rationales

Part a

A **KEY: This question could be answered because in the investigation, chromosomes from part of a leaf produced specialized cells in new leaves.**

B Cells, not chromosomes, divided during this investigation and produced new leaves, not new chromosomes.

C This investigation used only one set of chromosomes to produce specialized structures, so no evidence from this investigation can be used to answer this question.

D There is no evidence that the new leaves were produced by mutations instead of by the normal cellular processes that produce new leaves.

Part b

A This question could only be answered by comparing chromosomes, not cells.

B Transporting water and gases are functions that rely on systems of cells, not on chromosomes.

C Transporting water and gases are functions that rely on information in genes (parts of chromosomes), not numbers of complete chromosomes.

D **KEY: This question would help determine which genes in the cells of new leaves contain instructions for specific functions, such as transporting water and gases.**

Item 4: Standalone Item

Next Generation Science Standards Description

PE: HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [*Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]

SEP: Constructing Explanations and Designing Solutions: Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: PS1.B: Chemical Reactions: In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

DCI: ETS1.C: Optimizing the Design Solution: Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

CCC: Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

Item Type: Open-ended

Cognitive Complexity: Stimulus-High | SEP-High | DCI-High | CCC-Med

Number of Points: 4

Item on next page

This item brings students into the story line by asking them to refine the design of a chemical system by specifying changes in conditions that will decrease the amount of carbon dioxide in ocean water. The item aligns to the SEP by asking students to use scientific knowledge to refine a solution to a complex real-world problem that affects the ability of mollusks and corals to build shells and exoskeletons. The item aligns to the PS1.B DCI because students must use knowledge of a dynamic and condition-dependent equilibrium system that determines the numbers of all types of molecules in an aquarium tank. The item aligns to the ETS1.C DCI because students must use knowledge that criteria must be approached systematically and that trade-offs also need to be considered. The item aligns to the CCC because students must explain how the amount of carbon dioxide can be changed.

Some students work at a local aquarium. One of their tasks is to care for mollusks and corals in ocean water in a tank at the aquarium. The students need to make sure that the ocean water has the right balance of calcium ions (Ca^{2+}) and carbonate ions (CO_3^{2-}) that the mollusks and corals need to build their shells and skeletons.

To do this, the students need to ensure that calcium and carbonate ions are continuously added to the ocean water in the tank. The students know that ocean water contains calcium carbonate, which naturally breaks down into calcium and carbonate ions. The equilibrium relationship between the components in the water is shown in the equation.

Equilibrium Equation

$$\mathbf{CO_2 + H_2O + CaCO_3 \leftrightarrows Ca^{2+} + 2\ H^{+} + 2\ CO_3^{2-}}$$

The students decide to test the equilibrium relationships in the equation. With ocean water as an input, the students remove calcium ions (Ca^{2+}) as the ions form in the water in the tank. The students observe that as they remove calcium ions, more calcium ions form in the tank. They realize that this is an example of Le Chatelier's principle that describes the equilibrium relationships in the water.

The people who work at the aquarium tell the students that ocean water contains carbon dioxide (CO_2) and that increasing amounts of CO_2 in ocean water can cause some of the calcium carbonate ($CaCO_3$) in the shells and skeletons of ocean organisms to dissolve.

The students want to solve this problem by decreasing the amount of carbon dioxide in ocean water.

The stimulus for this item begins by presenting the phenomenon that the balance of calcium and carbonate ions in ocean water is important for mollusks and corals that use carbonate ions to build shells and skeletons. The hook is that students work at an aquarium and must continuously adjust the balance of these ions in the tank to keep the mollusks and corals in the tank alive. The phenomenon and hook are grade-level appropriate because many students have visited an aquarium or seen tanks with marine animals.

This question has two parts. Be sure to answer both parts of the question.

4. **a.** Describe one way students could decrease the amount of CO_2 in ocean water by applying Le Chatelier's principle.

b. Describe one constraint on implementing the change described in Part (a).

Part a is aligned to the SEP, PS1.B DCI, and CCC. Students describe how to refine a solution to the problem of too much CO_2 in the water by using their content knowledge of how to change one condition of the equilibrium system that determines the numbers of the molecules in the water to explain how to shift the system to decrease the amount of CO_2 in the water.

Part b is aligned to the SEP and ETS1.C DCI. Students describe a trade-off of their refined solution by using their content knowledge that trade-offs that affect how well their design solves the problem must be considered.

Scoring Rubric

Score	Description
4	The response demonstrates thorough use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response describes one way students could decrease the amount of CO_2 in ocean water by applying Le Chatelier's principle and describes one constraint on implementing the change described in part (a). The response • clearly applies science and engineering practices to provide an explanation or solution; • provides a coherent and accurate explanation or solution based on disciplinary core ideas; • reflects thorough understanding of complex ideas and crosscutting concepts; and • effectively applies and demonstrates complete understanding of the three dimensions.
3	The response demonstrates sufficient use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack some detail or information, or the response may contain minor errors in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
2	The response demonstrates limited use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack multiple details or information, or the response may contain major error(s) in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
1	The response demonstrates minimal use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
0	The response is inaccurate, is irrelevant, or contains no evidence of use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
Blank	No response

The scoring rubric specifies how a four-point response uses the dimensions of the PE and provides detail about how different levels of response meet the requirements of specific tasks in the item. All open-ended standalone items are four-point items.

Scoring Notes

$$CO_2 + H_2O + CaCO_3 \leftrightarrows Ca^{2+} + 2\,H^+ + 2\,CO_3^{2-}$$

a. They could solve the problem by removing calcium ions or adding calcium carbonate to ocean water. Either of these have the effect of shifting the reaction toward the products and decreasing the amount of CO_2 (while also increasing the amounts of calcium and carbonate ions available for shell/skeleton making).

b. The students would have to consider the costs of their solution, materials, energy requirements, and the reality of scaling up their design; the students would need to test their solution to see if it would work; OR any other plausible constraint.

The scoring notes provide information expected for a full credit/four-point response. They are written using the type of language most likely to be used by students.

Items 5–8: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

SEP: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

DCI: ESS2.D: Weather and Climate:

- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

CCC: Energy and Matter: The total amount of energy and matter in closed systems is conserved.

PE: HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

SEP: Using Mathematics and Computational Thinking: Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

DCI: ESS2.D: Weather and Climate: Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.

DCI: ESS3.D: Global Climate Change: Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Cluster Overview: Carbon in the Oceans

Item	Item Type	Alignment
5	Multiple Choice	HS-ESS2-6: SEP, DCI, CCC
6	Inline Choice	HS-ESS3-6: SEP, DCI, CCC
6 PBT	Multiple Choice	HS-ESS3-6: SEP, DCI, CCC
7	Multiple Choice—Multiple Choice	HS-ESS3-6: SEP, DCI, CCC
8	Multiple Choice—Inline Choice	HS-ESS2-6: DCI, CCC
8 PBT	Multiple Choice—Multiple Choice	HS-ESS2-6: DCI, CCC

The cluster consists of a phenomenon that allows overall item alignment across two PEs. While not every individual item in the cluster is three-dimensional, all items are all least two-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

Stimulus and Items on next pages

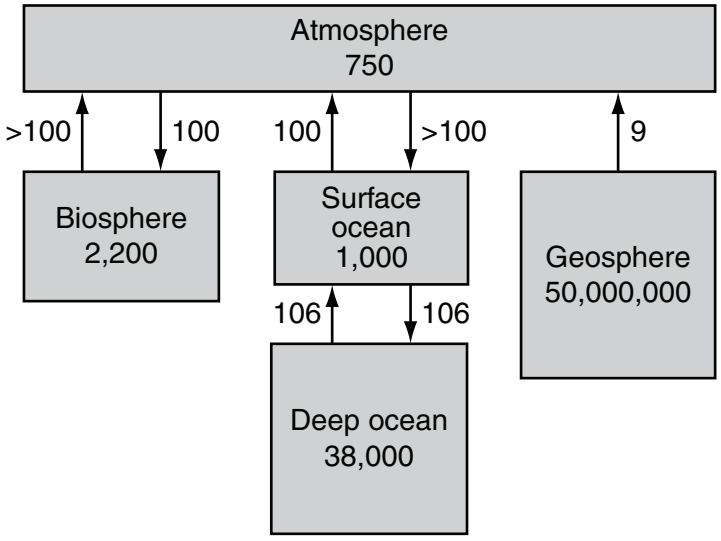
Read the information. Then answer the questions that follow.

Carbon in the Oceans

Students have learned that humans add large amounts of carbon to the atmosphere when carbon dioxide (CO_2) is released from burning fossil fuels. They want to learn more about how human activities affect the movement of carbon among Earth's spheres.

The students find a quantitative model that shows the amount of carbon stored in Earth's spheres and the amount that moves into and out of the atmosphere from the other spheres. The amounts shown are in 10^{12} kilograms per year.

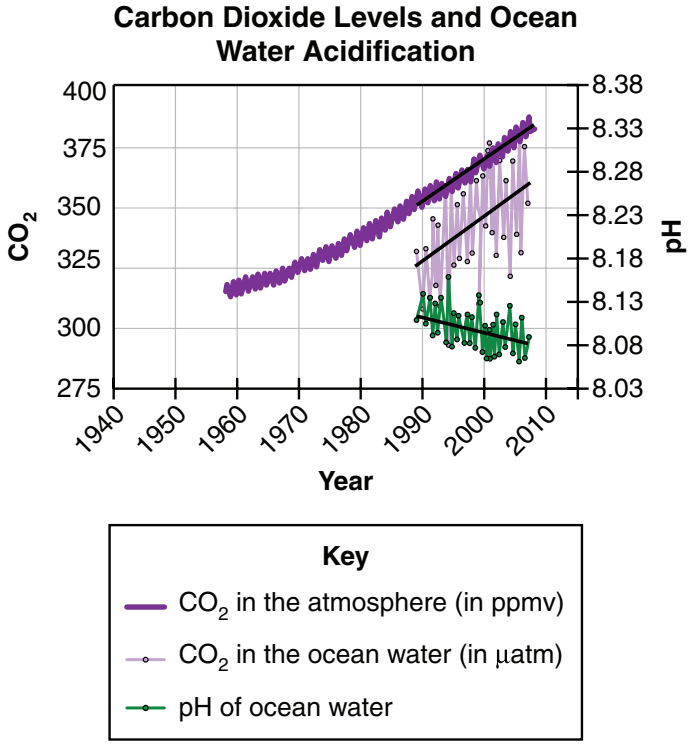
Global Movement of Carbon Model



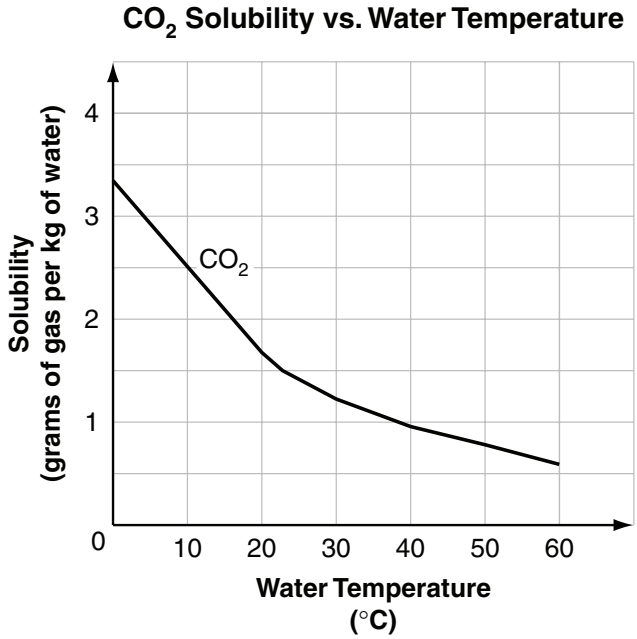
When the students research the effects of increasing carbon levels in the atmosphere, they learn that the carbon dioxide that oceans remove from the atmosphere increases the amount of carbon dioxide dissolved in ocean water and causes the ocean water to become more acidic. The amount of ocean acidification is measured by pH: As ocean water becomes more acidic, pH decreases. Ocean water that is more acidic causes damage to ocean organisms and the ecosystems they live in.

The stimulus for this cluster begins by presenting the phenomenon that human activities affect the movement of carbon among Earth's spheres. The hook is that a student learns that carbon that is released into the atmosphere affects marine organisms. The phenomenon and hook are grade-level appropriate because many students are aware that burning fossil fuels releases carbon dioxide and may learn at an aquarium or in the news that carbon dioxide in the atmosphere affects the oceans and organisms that live in the oceans.

As the students continue to research ocean acidification, they find a graph that shows how carbon dioxide in Earth's atmosphere and oceans and the pH of ocean water changed between 1960 and 2010.



The students also learn that the amount of carbon dioxide that can dissolve in ocean water depends on the temperature of the ocean water. The graph shows how the solubility of carbon dioxide depends on water temperature.



Item 5: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

SEP: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

DCI: ESS2.D: Weather and Climate: Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

CCC: Energy and Matter: The total amount of energy and matter in closed systems is conserved.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low | CCC-Low

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to develop a quantitative model to describe how burning fossil fuels affects the cycling of carbon. The item aligns to the SEP by asking students to describe how a graphical model of the relationships between natural Earth systems is affected by human activities. The item aligns to the DCI because students must use knowledge that the capture of carbon dioxide by plants causes only gradual atmospheric changes. The item aligns to the CCC because students must use the understanding that the total amount of matter is conserved as carbon moves in the closed Earth system.

5. As the students study the model, they realize that the carbon released by burning fossil fuels moves only a small amount of carbon into the atmosphere every year.

Which statement **best** describes how burning fossil fuels is a problem for Earth's spheres and is supported by the model?

A Burning fossil fuels adds less carbon to the atmosphere than the oceans.

B Burning fossil fuels moves carbon from the biosphere into the atmosphere.

C Millions of years ago, the carbon in fossil fuels was part of plants in the biosphere.

D Carbon released from burning fossil fuels is not quickly recycled back to Earth's other spheres.

This item is aligned to the SEP, DCI, and CCC. Students describe how the relationships shown in the model are affected by burning fossil fuels by using their content knowledge that human activity is causing rapid, not gradual, atmospheric changes in carbon dioxide and the understanding that matter is conserved as carbon moves between Earth's spheres.

Scoring Key

Correct Response: D

Distractor Rationales

A Adding less to the atmosphere would not make burning fossil fuels a problem.

B The model shows that burning fossil fuels moves carbon from the geosphere, not from the biosphere, into the atmosphere.

C While true, this does not describe how burning fossil fuels is a problem and isn't supported by the model.

D KEY: Burning fossil fuels moves carbon quickly from the geosphere to the atmosphere. The model does not show how to move carbon back into the geosphere, nor how to quickly increase photosynthesis to move more carbon into the biosphere, nor how to increase the amount of carbon that dissolves in water to move more carbon into the oceans.

Item 6: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

SEP: Using Mathematics and Computational Thinking: Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

DCI: ESS3.D: Global Climate Change: Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Item Type: Inline Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to use computational representations to describe how the relationship between Earth's oceans and atmosphere is being modified by human activity. The item aligns to the SEP by asking students to use graphs and a model to support a claim. The item aligns to the DCI because students must use knowledge of how interactions between the ocean and atmosphere are modified by human activity. The item aligns to the CCC because students must analyze inputs and outputs of Earth systems.

6. Select the words that describe a claim that is supported by the model and graphs.

By 2100, Earth's oceans will be [more, less] acidic because of [increasing, decreasing] levels of carbon in Earth's atmosphere.

Scoring Key

Correct Response:
By 2100, Earth's oceans will be [**more**, less] acidic because of [**increasing**, decreasing] levels of carbon in Earth's atmosphere.

This item is aligned to the SEP, DCI, and CCC. Students make a claim that is supported by a model and graphs by using their content knowledge of how interactions between Earth's oceans and atmosphere are modified by human activity and the understanding that increasing the amount of carbon that is output to the atmosphere changes the amount of carbon that is input to the oceans.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 6: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

SEP: Using Mathematics and Computational Thinking: Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

DCI: ESS3.D: Global Climate Change: Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to use computational representations to describe how the relationship between Earth's oceans and atmosphere is being modified by human activity. The item aligns to the SEP by asking students to use graphs and a model to support a claim. The item aligns to the DCI because students must use knowledge of how interactions between the ocean and atmosphere are modified by human activity. The item aligns to the CCC because students must analyze inputs and outputs to the atmosphere and oceans to support the claim.

6. Which claim is supported by the model and graphs?

A By 2100, Earth's oceans will be more acidic because of increasing levels of carbon in Earth's atmosphere.

B By 2100, Earth's oceans will be more acidic because of decreasing levels of carbon in Earth's atmosphere.

C By 2100, Earth's oceans will be less acidic because of increasing levels of carbon in Earth's atmosphere.

D By 2100, Earth's oceans will be less acidic because of decreasing levels of carbon in Earth's atmosphere.

This item is aligned to the SEP, DCI, and CCC. Students make a claim that is supported by a model and graphs by using their content knowledge of how interactions between Earth's oceans and atmosphere are modified by human activity and the understanding that increasing the amount of carbon that is output to the atmosphere changes the amount of carbon that is input to the oceans.

Scoring Key

Correct Response: A

Distractor Rationales

A **KEY: More carbon in the atmosphere increases the acidity of Earth's oceans.**

B The graph shows that increasing, not decreasing, atmospheric carbon causes Earth's oceans to become more acidic.

C The graph shows that increasing atmospheric carbon causes Earth's oceans to become more, not less, acidic.

D The graph shows that ocean acidity and amount of carbon in the atmosphere are both increasing, not decreasing.

Item 7: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

SEP: Using Mathematics and Computational Thinking: Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

DCI: ESS3.D: Global Climate Change: Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-High | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use a computational representation to describe the relationships between carbon dioxide solubility, ocean acidification, and ocean ecosystems. The item aligns to the SEP by asking students to use a graph to support a claim. The item aligns to the DCI because students must use knowledge of how human activity is modifying interactions between the ocean, atmosphere, and biosphere. The item aligns to the CCC because students must analyze inputs and outputs to oceans and ocean ecosystems to support the claim.

This question has two parts. Be sure to answer both parts of the question.

7. As human populations and carbon emissions continue to increase, ocean ecosystems will continue to be damaged.

Part a

Based on the CO_2 Solubility vs. Water Temperature graph, which part of Earth's oceans is **most likely** to contain ecosystems that have been damaged by ocean acidification?

A cold water ecosystems near the poles

B warm water ecosystems near the poles

C cold water ecosystems near the equator

D warm water ecosystems near the equator

Part b

Which statement describes how evidence from the graph supports the claim in Part (a)?

A Half as much carbon dioxide dissolves in water at 50°C as dissolves in water at 30°C.

B Half as much carbon dioxide dissolves in water at 40°C as dissolves in water at 60°C.

C Twice as much carbon dioxide dissolves in water at 0°C as dissolves in water at 20°C.

D Twice as much carbon dioxide dissolves in water at 40°C as dissolves in water at 10°C.

Part a is aligned to the SEP, DCI, and CCC. Students use data in a graph to support a claim by using their content knowledge of how interactions between Earth's oceans and atmosphere are modified by human activity and the understanding that increasing the amount of atmospheric carbon that is input to the oceans changes the acidity of ocean water that is input to ocean ecosystems.

Part b is aligned to the SEP and CCC. Students describe how graphed data support the claim by using the understanding that the amount of atmospheric carbon that is input to the ocean water system affects the amount of dissolved carbon that is input to ocean water.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: C

Distractor Rationales

Part a

A **KEY: According to the graph, more CO_2 dissolves in colder water, which results in more acidic water, hence more damage to ecosystems.**

B There are no warm-water ecosystems near the poles, and the graph shows that warmer temperatures are associated with less dissolved CO_2, therefore less acidic water and less damage to ecosystems.

C There are no cold-water ecosystems near the equator, even though more CO_2 dissolves in colder water, making the water more acidic and causing more damage.

D Less CO_2 dissolves in warmer water, making the water less acidic and causing less damage.

Part b

A Less CO_2 dissolves at 50°C than at 30°C, but not half as much.

B More CO_2, not less, dissolves at lower temperatures.

C **KEY: The graph shows about 3.25 grams of gas dissolve in each kilogram of water when the water is 0°C while only about half that much (about 1.6 grams gas per kilogram water) dissolves in water that is 20°C.**

D D. Less CO_2, not more, dissolves at higher temperatures.

Item 8: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

DCI: ESS2.D: Weather and Climate: Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

CCC: Energy and Matter: The total amount of energy and matter in closed systems is conserved.

Item Type: Multiple Choice—Inline Choice

Cognitive Complexity: Stimulus-Med | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to describe the cycling of carbon among ocean water, kelp, and sea otters. The item aligns to the DCI because students must use knowledge that changes in the atmosphere affect carbon cycling between the hydrosphere and biosphere. The item aligns to the CCC because students must use the understanding that the total amount of carbon is conserved in the closed Earth system.

This question has two parts. Be sure to answer both parts of the question.

8. The students learn that underwater forests made of plants like kelp store carbon in the same way that trees in forests on land store carbon. They are surprised to learn that organisms that live in kelp forests can increase the amount of carbon stored by the kelp. For example, scientists have determined that when sea otters live in kelp forests, the forests store up to 12 times more carbon than kelp forests without sea otters.

Part a

Which statement describes how sea otters can increase the amount of carbon stored by the biosphere?

A Sea otters eat organisms that eat kelp, which allows the kelp forest to grow larger.

B Sea otters only live in kelp forests that are small enough to have low levels of carbon.

C Sea otters only live in kelp forests that release large amounts of carbon into the water.

D Sea otters are less likely to eat organisms that live in kelp forests with large amounts of dissolved carbon.

Part a is aligned to the DCI and CCC. Students use their content knowledge of carbon cycling between the hydrosphere and biosphere and the understanding that the carbon cycle conserves the total amount of carbon to explain how sea otters can increase the amount of carbon stored in the biosphere.

Part b

Select the words that describe the effect of sea otters on carbon in the hydrosphere.

The sea otter population [directly, indirectly] causes the amount of carbon in ocean water to [increase, decrease].

Part b is aligned to the DCI and CCC. Students use their content knowledge of carbon cycling between the hydrosphere and biosphere and the understanding that the carbon cycle conserves the total amount of carbon to explain how sea otters affect the amount of carbon stored in the hydrosphere.

Scoring Key

Part a

Correct Response: A

Part b

Correct Response:
The sea otter population [directly, **indirectly**] causes the amount of carbon dissolved in ocean water to [increase, **decrease**].

Distractor Rationales

Part a

A **KEY: A larger kelp forest will store more carbon.**

B If that is true, then sea otters do not increase the amount of stored carbon.

C Kelp stores carbon by taking carbon in from the water. Releasing large amounts of carbon into the water would decrease, not increase, the amount of stored carbon.

D More sea otters cause kelp forests to store, not dissolve, more carbon. If sea otters have less food, there will be fewer otters and less, not more, stored carbon.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 8: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

DCI: ESS2.D: Weather and Climate: Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

CCC: Energy and Matter: The total amount of energy and matter in closed systems is conserved.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to describe the cycling of carbon among ocean water, kelp, and sea otters. The item aligns to the DCI because students must use knowledge that changes in the atmosphere affect carbon cycling between the hydrosphere and biosphere. The item aligns to the CCC because students must use the understanding that the total amount of carbon is conserved in the closed Earth system.

This question has two parts. Be sure to answer both parts of the question.

8. The students learn that underwater forests made of plants like kelp store carbon in the same way that trees in forests on land store carbon. They are surprised to learn that organisms that live in kelp forests can increase the amount of carbon stored by the kelp. For example, scientists have determined that when sea otters live in kelp forests, the forests store up to 12 times more carbon than kelp forests without sea otters.

Part a

Which statement describes how sea otters can increase the amount of carbon stored by the biosphere?

A Sea otters eat organisms that eat kelp, which allows the kelp forest to grow larger.

B Sea otters only live in kelp forests that are small enough to have low levels of carbon.

C Sea otters only live in kelp forests that release large amounts of carbon into the water.

D Sea otters are less likely to eat organisms that live in kelp forests with large amounts of dissolved carbon.

Part a is aligned to the DCI and CCC. Students use their content knowledge of carbon cycling between the hydrosphere and biosphere and the understanding that the carbon cycle conserves the total amount of carbon to explain how sea otters can increase the amount of carbon stored in the biosphere.

Part b

Which statement describes the effect of sea otters on carbon in the hydrosphere?

A The sea otter population directly causes the amount of carbon in ocean water to increase.

B The sea otter population directly causes the amount of carbon in ocean water to decrease.

C The sea otter population indirectly causes the amount of carbon in ocean water to increase.

D The sea otter population indirectly causes the amount of carbon in ocean water to decrease.

Part b is aligned to the DCI and CCC. Students use their content knowledge of carbon cycling between the hydrosphere and biosphere and the understanding that the carbon cycle conserves the total amount of carbon to explain how sea otters affect the amount of carbon stored in the hydrosphere.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: D

Distractor Rationales

Part a

A **KEY: A larger kelp forest will store more carbon.**

B If that is true, then sea otters do not increase the amount of stored carbon.

C Kelp takes carbon in from the water. Releasing large amounts of carbon into the water would decrease, not increase, the amount of stored carbon.

D More sea otters cause kelp forests to store, not dissolve, more carbon. If sea otters have less food, there will be fewer otters and less, not more, stored carbon.

Part b

A Sea otters indirectly, not directly, cause the kelp forest, not ocean water, to store more carbon.

B Sea otters indirectly, not directly, help the kelp forest move carbon from ocean water to the forest.

C Sea otters indirectly cause the amount of carbon in ocean water to decrease, not increase, as more carbon is stored in the kelp forest.

D **KEY: Sea otters eat organisms that eat kelp, which indirectly helps the kelp forest grow larger and store more carbon, which decreases the amount of carbon in ocean water.**

Items 9–12: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: ESS2.A: Earth Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

DCI: ESS2.D: Weather and Climate: The foundation for Earth's global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

PE: HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

SEP: Constructing Explanations and Designing Solutions: Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ESS3.C: Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Cluster Overview: Land Use and Erosion

Item	Item Type	Alignment
9	Multiple Choice	HS-ESS2-2: SEP, DCI
10	Multiple Choice—Inline Choice	HS-ESS2-2: SEP, DCI, CCC
10 PBT	Multiple Choice—Multiple Choice	HS-ESS2-2: SEP, DCI, CCC
11	Multiple Choice	HS-ESS3-4: SEP, DCI, CCC
12	Multiple Choice—Multiple Choice	HS-ESS3-4: SEP, DCI, CCC

Stimulus and Items on next pages

The cluster consists of a phenomenon that allows overall item alignment across two PEs. While not every individual item in the cluster is three-dimensional, all items are all least two-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

Read the information. Then answer the questions that follow.

Land Use and Erosion

A student lives in a forested area. A logging company wants to harvest trees from land near her home by clearcutting the area. When a forested area is clearcut, all the trees in the area are cut down. The clearcut area is often replanted with one of the following:

- tree plantations to harvest wood
- tree crops like nuts and fruits
- rotating food crops like grains and vegetables

The land that is being considered for clearcutting and replanting has steep hills and is very close to a stream. The student wonders how this change in land use could affect the environment.

She finds a study that assesses how much soil disturbance is caused by five different logging methods. Each logging method uses one of two cut patterns: harvesting trees selectively by cutting down only the large trees in an area, or clearcutting. The logging methods studied vary in the amount of trees and ground cover removed, the number of roads built, and the way logs are stored. These differences result in different amounts of bare soil after the logging.

The table shows the percentage of bare soil that results from each logging method.

Soil Disturbance from Logging

Logging Method	Cut Pattern	From Tree Removal	From Road Building	From Log Storage
1	Selective cut	15.0	25–30	none
2	Clearcut	14.1	6.2	3.6
3	Selective cut	15.5	2.7	5.7
4	Clearcut	12.1	2.0	none
5	Clearcut	6.0	1.2	none

The stimulus for this cluster begins by presenting the phenomenon that clearcutting and replanting an area affect the environment. The hook is that a student lives near an area that will be clearcut. The phenomenon and hook are grade-level appropriate because many students have experience with areas that have been logged, clearcut, or replanted.

Next, the student finds a study that investigates the amount of soil erosion that results from different types of land use. The table shows the amount of erosion in tons per hectare per year.

Soil Erosion and Land Use

Type of Land Use	Erosion (tons/ha/yr)
Natural forest, undisturbed soil	6.16
Tree plantation, undisturbed soil	6.20
Tree plantation, bare soil	104.80
Tree crops, ground cover	5.60
Tree crops, bare soil	182.90
Rotating food crops, ground cover	7.40
Rotating food crops, bare soil	70.05

Item 9: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: ESS2.A: Earth Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to analyze data to make a claim that changes in land use can create feedback that causes changes in erosion. The item aligns to the SEP by asking students to analyze data in order to make a claim. The item aligns to the DCI because students must use the understanding that interactions among Earth systems cause feedback effects that can increase the original changes to make their claim.

9. Which description of the effect of land use on erosion is supported by the Soil Erosion and Land Use table?

A Planting tree crops with ground cover after logging a natural forest could decrease the amount of erosion.

B Planting rotating food crops with ground cover after logging a natural forest could decrease the amount of erosion.

C Planting tree plantations without ground cover after logging a natural forest could decrease the amount of erosion.

D Planting rotating food crops without ground cover after logging a natural forest could decrease the amount of erosion.

This item is aligned to the SEP and DCI. Students make a claim that is supported by their analysis of data and their content knowledge that interactions among Earth systems cause feedback effects that can decrease the original changes.

Scoring Key

Correct Response: A

Distractor Rationales

A **KEY: According to the table, the amount of erosion decreases from 6.16 tons/ha/yr in a natural forest with undisturbed soil to 5.60 tons/ha/yr when tree crops are planted with ground cover.**

B Erosion would increase from 6.16 tons/ha/yr to 7.40 tons/ha/yr if rotating food crops with ground cover were planted.

C Erosion would increase from 6.16 tons/ha/yr to 104.840 tons/ha/yr if tree plantations without ground cover were planted.

D Erosion would increase from 6.16 tons/ha/yr to 70.05 tons/ha/yr if rotating food crops without ground cover were planted.

Item 10: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: ESS2.A: Earth Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Item Type: Multiple Choice—Inline Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to analyze data to make a claim that logging can create feedback that causes changes in the amount of disturbed soil. The item aligns to the SEP by asking students to analyze data in order to make a claim. The item aligns to the DCI because students must use knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes. The item aligns to the CCC because students must use understanding of how feedback can stabilize or destabilize a system to make their claim.

This question has two parts. Be sure to answer both parts of the question.

10. **Part a**

Which claim is supported by the Soil Disturbance from Logging table?

A Road building during clearcutting results in less soil disturbance than during selective cutting.

B Tree removal during selective cutting results in more soil disturbance than during clearcutting.

C Clearcutting results in more soil disturbance than selective cutting because more logs are stored.

D Selective cutting results in less soil disturbance than clearcutting because fewer trees are cut down.

Part a is aligned to the SEP and DCI. Students make a claim that is supported by their analysis of data and their content knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes.

Part b

Select the words that describe a feedback loop between the biosphere and the geosphere caused by logging.

When trees are planted on bare soil, a [positive, negative] feedback loop occurs. Planting the trees [increases, decreases] the amount of ground cover.

This causes the amount of erosion to [increase, decrease].

This change causes [increased erosion, decreased erosion, increased ground cover, decreased ground cover].

Part b is aligned to the DCI and CCC. Students use their content knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes to describe how the type of feedback caused by logging destabilizes the system.

Scoring Key

Part a

Correct Response: B

Part b

Correct Response:
When trees are planted on bare soil, a [**positive**, negative] feedback loop occurs.
Planting the trees [**increases**, decreases] the amount of ground cover.

This causes the amount of erosion to [increase, **decrease**].

This change causes [increased erosion, decreased erosion, **increased ground cover**, decreased ground cover].

Distractor Rationales

Part a

A The disturbance from road building in clearcut method 2 is less than selective cut method 1 but more than selective cut method 3, so this claim is not true for all methods.

B KEY: The disturbance from tree removal is larger for selective cut methods 1 and 3 than for any of the clearcut methods, so this claim is always true.

C The disturbance from storing logs in clearcut method 2 is less than from selective cut method 3, so this claim is not true for all methods.

D While fewer trees are cut down, there are no data in the table to support this claim and the total amount of disturbance from selective cutting is greater than (40-45) or equal to (23.9), the total from the three clearcut methods (23.9, 14.1, or 7.2).

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 10: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: ESS2.A: Earth Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to analyze data to make a claim that logging can create feedback that causes changes in the amount of disturbed soil. The item aligns to the SEP by asking students to analyze data in order to make a claim. The item aligns to the DCI because students must use knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes. The item aligns to the CCC because students must use understanding of how feedback can stabilize or destabilize a system to make their claim.

This question has two parts. Be sure to answer both parts of the question.

10. **Part a**

Which claim is supported by the Soil Disturbance from Logging table?

A Road building during clearcutting results in less soil disturbance than during selective cutting.

B Tree removal during selective cutting results in more soil disturbance than during clearcutting.

C Clearcutting results in more soil disturbance than selective cutting because more logs are stored.

D Selective cutting results in less soil disturbance than clearcutting because fewer trees are cut down.

Part a is aligned to the SEP and DCI. Students make a claim that is supported by their analysis of data and their content knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes.

Part b

Which set of statements describes a feedback loop between the biosphere and the geosphere caused by logging?

A
- When trees are planted on bare soil, a positive feedback loop occurs.
- Planting the trees increases the amount of ground cover.
- This causes the amount of erosion to decrease.
- This change causes increased ground cover.

B
- When trees are planted on bare soil, a positive feedback loop occurs.
- Planting the trees decreases the amount of ground cover.
- This causes the amount of erosion to increase.
- This change causes decreased ground cover.

C
- When trees are planted on bare soil, a negative feedback loop occurs.
- Planting the trees increases the amount of ground cover.
- This causes the amount of erosion to decrease.
- This change causes increased ground cover.

D
- When trees are planted on bare soil, a negative feedback loop occurs.
- Planting the trees decreases the amount of ground cover.
- This causes the amount of erosion to increase.
- This change causes decreased ground cover.

Part b is aligned to the DCI and CCC. Students use their content knowledge that interactions among Earth systems cause feedback effects that can increase or decrease the original changes to describe how the type of feedback caused by logging destabilizes the system.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: A

Distractor Rationales

Part a

A The disturbance from road building in clearcut method 2 is less than selective cut method 1 but more than selective cut method 3, so this claim is not true for all methods.

B KEY: The disturbance from tree removal is larger for selective cut methods 1 and 3 than for any of the clearcut methods, so this claim is always true.

C The disturbance from storing logs in clearcut method 2 is less than from selective cut method 3, so this claim is not true for all methods.

D While fewer trees are cut down, there are no data in the table to support this claim and the total amount of disturbance from selective cutting is greater than (40-45) or equal to (23.9), the total from the three clearcut methods (23.9, 14.1, or 7.2).

Part b

A KEY: This describes the positive feedback loop as planting trees increases ground cover which decreases erosion, which increases ground cover, which decreases erosion, etc.

B Planting the trees increases, not decreases, the amount of ground cover. This causes the amount of erosion to decrease, not increase, and this change causes increased, not decreased, ground cover.

C A positive, not negative, feedback loop occurs.

D A positive, not negative, feedback loop occurs. Planting the trees increases, not decreases, the amount of ground cover. This causes the amount of erosion to decrease, not increase, and this change causes increased, not decreased, ground cover.

Item 11: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

SEP: Constructing Explanations and Designing Solutions: Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ESS3.C: Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to evaluate solutions that reduce the impact of logging on a forest. The item aligns to the SEP by asking students to use evidence to evaluate the solutions. The item aligns to the DCI because students must use knowledge that technologies can reduce ecosystem degradation. The item aligns to the CCC because students must use the understanding that feedback can stabilize or destabilize a system in their evaluation of the solutions.

11. A logging company is choosing a logging method to selectively cut an area of forest. The company wants to use a method that will reduce human impact and stabilize the amount of erosion in the area. Based on the Soil Disturbance from Logging table, should the logging company use method 1 or method 3?

A Method 3, because removing fewer trees will result in a smaller increase in erosion than method 1.

B Method 3, because clearing less land for roads will result in a smaller increase in erosion than method 1.

C Method 1, because not using land to store logs will result in a smaller increase in erosion than method 3.

D Method 1, because leaving less soil bare after logging will result in a smaller increase in erosion than method 3.

This item is aligned to the SEP, DCI, and CCC. Students evaluate solutions by using evidence, their content knowledge that technology can reduce ecosystem degradation, and their understanding of how feedback can stabilize a system.

Scoring Key

Correct Response: B

Distractor Rationales

A The data show that a larger percentage of land is left bare from logging in Method 3, which indicates that more, not fewer, trees were removed.

B KEY: The data show that clearing less land for roads results in less erosion than in the selective cutting in Method 1.

C Storage sites and trails are not needed, but roads leave a larger, not smaller, percentage of bare soil than storage sites and trails in Method 3.

D Although a smaller percentage of land is left bare from logging, the total amount of bare soil is greater, not less, than in Method 1.

Item 12: Cluster Item

Next Generation Science Standards Description

PE: HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

SEP: Constructing Explanations and Designing Solutions: Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ESS3.C: Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to refine a solution that reduces the impact of logging on a forest. The item aligns to the SEP by asking students to use evidence about logging methods and land uses to refine a solution to problems caused by logging. The item aligns to the DCI because students must use knowledge that technologies can reduce ecosystem degradation. The item aligns to the CCC because students must use the understanding that feedback can stabilize a system in their refinement of the solution.

This question has two parts. Be sure to answer both parts of the question.

12. The logging company decides to clearcut the forest near the student's home.

Part a

Based on information in the tables, which logging method and land use is **most likely** to reduce the human impact on the ecosystem near the student's home?

A Clearcut with Method 2 and then plant tree crops with ground cover.

B Clearcut with Method 4 and then plant tree crops with ground cover.

C Clearcut with Method 2 and then plant rotating food crops with ground cover.

D Clearcut with Method 4 and then plant rotating food crops with ground cover.

Part a is aligned to the SEP, DCI, and CCC. Students use evidence, their content knowledge that technology can reduce ecosystem degradation, and their understanding of how feedback can stabilize a system to choose a combination of solutions that is a refinement of the original solutions.

Part b

Which statement describes a reason for the answer to Part (a)?

A This logging method and land use will result in less bare soil and less erosion.

B This logging method and land use will result in more bare soil but less erosion.

C This logging method and land use will result in the smallest increase in bare soil and erosion.

D This logging method and land use will result in the largest decrease in bare soil and erosion.

Part b is aligned to the SEP, DCI, and CCC. Students use evidence, their content knowledge that technology can reduce ecosystem degradation, and their understanding of how feedback can stabilize a system to explain why the combination of solutions is a refinement of the original solutions.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: C

Distractor Rationales

Part a

A Method 2 increases bare soil more than Method 4, even though planting tree crops actually decreases erosion.

B KEY: Method 4 increases bare soil less than Method 2 and planting tree crops decreases erosion.

C Method 2 increases bare soil more than Method 4 and planting food crops increases erosion.

D Even though Method 4 increases bare soil less than Method 2, planting food crops increases erosion.

Part b

A None of the combinations results in less bare soil.

B While this is true for one of the options in Part (a), this is not the best option.

C KEY: This combination increases the bare soil the least and results in the least erosion.

D None of the combinations results in less bare soil.

Session 2: Items 13–24

Item 13: Standalone Item

Next Generation Science Standards Description

PE: HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

SEP: Obtaining, Evaluating, and Communicating Information: Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

DCI: LS4.A: Evidence of Common Ancestry and Diversity: Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

CCC: Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Low | DCI-Med | CCC-High

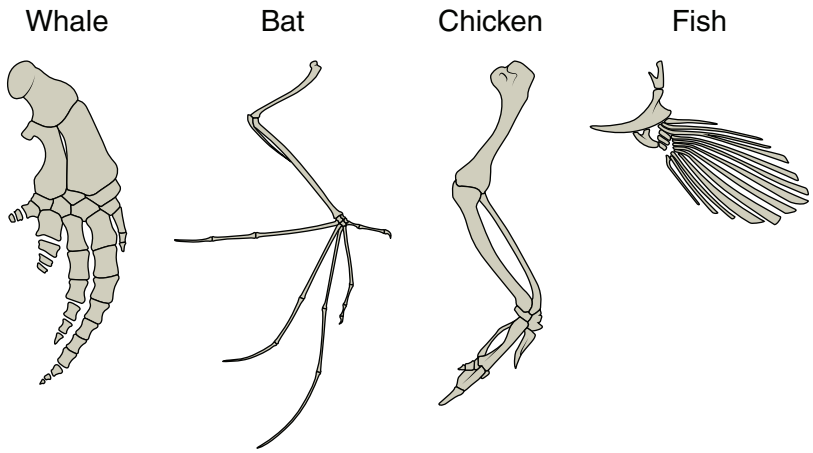
Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use a cladogram and information about anatomical structures to evaluate the common ancestry of four organisms. The item aligns to the SEP by asking students to communicate how scientific information supports claims about organisms and common ancestry. The item aligns to the DCI because students must use knowledge of how anatomical evidence and the branching of multiple lines of descent are evidence of evolution. The item aligns to the CCC because students must use the patterns observed in the anatomical structures and cladogram as evidence of causality explained by a common ancestor.

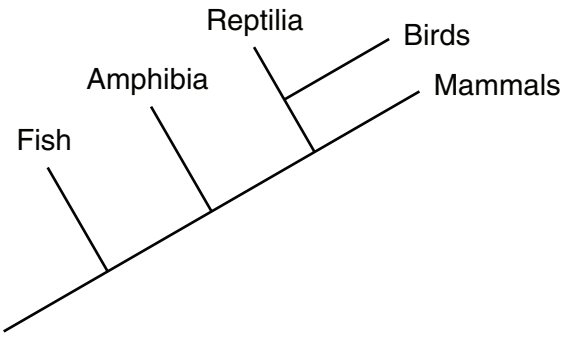
A student is studying how the bone structure of animals has changed over time. The student finds a diagram that shows bones in the forelimbs of four vertebrates. Whales and bats are mammals. Chickens are birds.

Forelimbs of Four Vertebrates



The student also finds a cladogram showing the evolutionary relationships among vertebrates.

Vertebrates Cladogram



The stimulus for this item begins by presenting the phenomenon that bone structures have changed over time. The hook is that a student finds evidence of this change over time. The phenomenon and hook are grade-level appropriate because many students are interested in animal skeletons and read about evolutionary relationships in news articles.

This question has two parts. Be sure to answer both parts of the question.

13. Part a

Based on evidence in the diagram and the cladogram, which two animals have the **most** similar DNA sequences?

A whale and bat

B fish and whale

C bat and chicken

D chicken and fish

Part b

Which statement describes a reason for the answer to Part (a)?

A The two animals have similar bone structures.

B The two animals adapted to the same environment.

C The two animals have the most recent common ancestor.

D The two animals have forelimbs adapted for the same function.

Part a is aligned to the SEP, DCI, and CCC. Students use scientific information to make a claim by using patterns that provide evidence of how different animals are related and their content knowledge of how anatomical evidence and branching lines of descent are evidence of evolution.

Part b is aligned to the SEP, DCI, and CCC. Students use scientific information to support their claim by using patterns that provide evidence of how different animals are related and their content knowledge of how anatomical evidence and branching lines of descent are evidence of evolution.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: C

Distractor Rationales

Part a

A **KEY: Whales and bats have the most similar bone structures and are both mammals.**

B Fish and whales both live in the same environment but their forelimbs are very different and they are not close in the cladogram.

C Bats and chickens both use similar forelimbs to fly but one is a mammal and the other is a bird.

D Chickens and fish are not closely related based on a comparison of their forelimbs or on the cladogram.

Part b

A Similar environments can result in species that have similar bone structures even though the species have very different DNA sequences and are not closely related.

B Similar adaptations in different species will not cause the species to have similar DNA sequences.

C **KEY: The whale and the bat are both mammals, which provides evidence that they both evolved from a more recent common ancestor than the other organisms.**

D DNA similarities depend more on common ancestry than on form and function.

Item 14: Standalone Item

Next Generation Science Standards Description

PE: HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

SEP: Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

DCI: PS1.C: Nuclear Processes: Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

CCC: Energy and Matter: In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to develop models that describe the changes in the composition of the nucleus during the nuclear process in fusion bombs. The item aligns to the SEP by asking students to develop graphical and verbal models that show the relationship between changes in nuclear particles and nuclear fusion. The item aligns to the DCI because students must use knowledge of how nuclear fusion changes the neutrons and protons in the nucleus. The item aligns to the CCC because students must use the understanding that the total number of protons plus neutrons is conserved during nuclear processes.

This question has two parts. Be sure to answer both parts of the question.

14. A student who is interested in nuclear fusion finds an article on the first successful detonation of a nuclear fusion bomb.

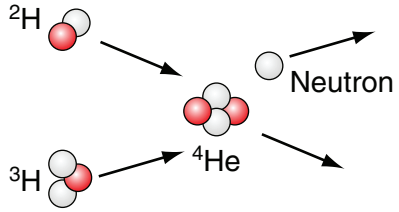
The stimulus for this item begins by presenting the phenomenon that nuclear fusion is used in bombs. The hook is that a student is interested in what happens when a fusion bomb explodes. The phenomenon and hook are grade-level appropriate because many students are interested in nuclear reactions.

Part a

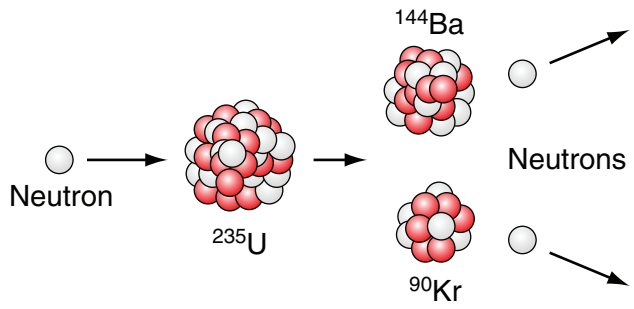
The student wants to use a model of nuclear fusion to show the process that occurs inside bombs.

Which model could the student use?

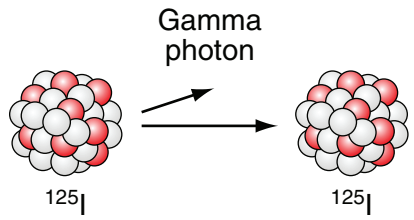
A



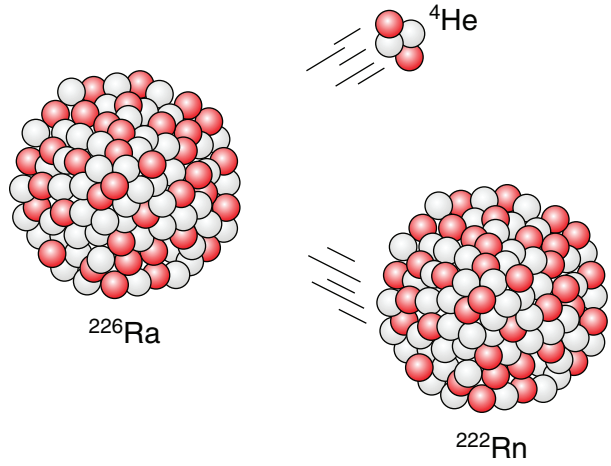
B



C



D



Part a is aligned to the SEP and DCI. Students select a graphical model that shows the relationship between particles before and after nuclear fusion by using their content knowledge of how nuclear fusion changes the neutrons and protons in the nucleus.

Part b

Which statement about nuclear processes is supported by the models in Part (a)?

A During nuclear processes, the total number of atoms is conserved.

B During nuclear processes, the total number of protons is conserved.

C During nuclear processes, the total number of neutrons is conserved.

D During nuclear processes, the total number of neutrons and protons is conserved.

Part b is aligned to the SEP, DCI, and CCC. Students develop a verbal model that is supported by the graphical models by using their content knowledge of how nuclear fusion changes the neutrons and protons in the nucleus and the understanding that all nuclear processes conserve the total number of protons plus neutrons.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: D

Distractor Rationales

Part a

A **KEY: This model shows nuclear fusion.**

B This model shows nuclear fission.

C This model shows gamma decay.

D This model shows alpha decay.

Part b

A The models show that the total number of atoms is not conserved. Only Model A shows two groups of particles before and after.

B The models show that the total number of protons is not conserved. Only Model C shows the same element, the same atomic number, before and after.

C The models show that the total number of neutrons is not conserved. While the atomic masses are the same in the models, the number of neutrons changes because the number of protons changes.

D **KEY: The models show that the total number of protons and neutrons, the total atomic mass, is conserved.**

Item 15: Standalone Item

Next Generation Science Standards Description

PE: HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

SEP: Constructing Explanations and Designing Solutions: Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

DCI: ESS3.B: Natural Hazards: Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Inline Choice—Multiple Choice

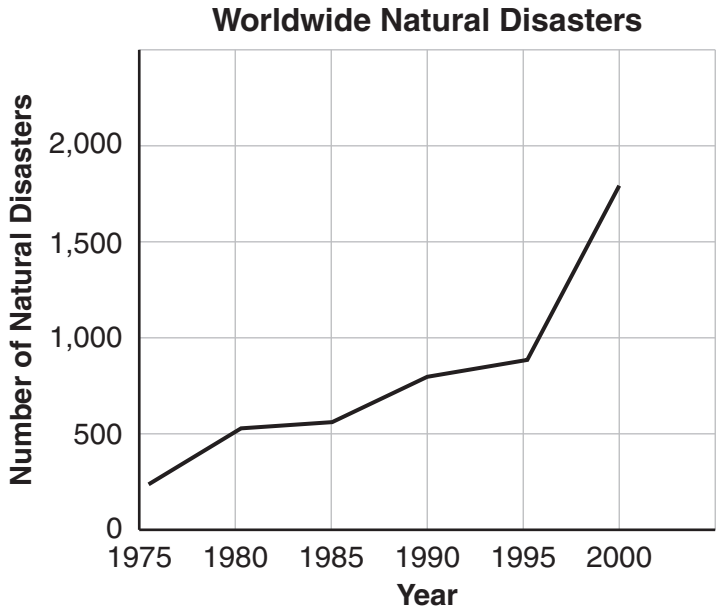
Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

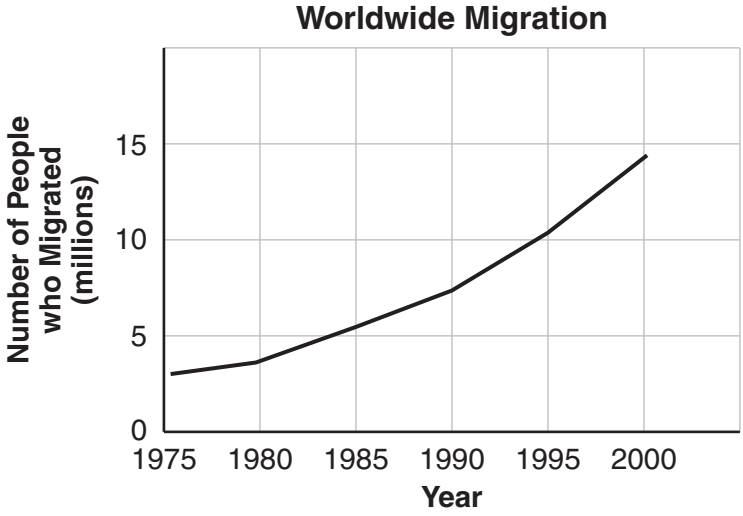
Item on next page

This item brings students into the story line by asking them to use evidence to construct an explanation about how the frequency of natural disasters has influenced human migration. The item aligns to the SEP by asking students to construct an explanation based on evidence. The item aligns to the DCI because students must use knowledge of how natural disasters have driven human migrations. The item aligns to the CCC because students must use evidence to make a claim about how migration is caused by natural disasters.

A student is studying the effects of climate change and natural disasters on human populations. The student finds a graph that shows the number of natural disasters between 1975 and 2000.



The student finds another graph that shows the number of people who migrated from low-income countries during the same time period.



The stimulus for this item begins by presenting the phenomenon that human populations have been influenced by climate change and natural disasters. The hook is that a student finds data on natural disasters and the number of people who migrate. The phenomenon and hook are grade-level appropriate because many students hear about natural disasters and human migrations on the news.

This question has two parts. Be sure to answer both parts of the question.

15. Part a

Select the choices that explain the trends shown in the graphs.

The largest number of natural disasters occurred between [1985–1990, 1990–1995, 1995–2000], which corresponded to a [sharp increase, slight increase, sharp decrease, slight decrease] in the rate of migration.

Part a is aligned to the SEP and CCC. Students construct an explanation using evidence and their understanding of the cause and effect relationship between migration and natural disasters.

Part b

Which claim about natural disasters is supported by the graphs?

A The number of natural disasters will decrease in the future.

B Natural disasters are the most important cause of migration.

C Natural disasters increase the difficulty of finding the resources needed to survive.

D The number of people who migrate will stop increasing as people become settled in their new country.

Part b is aligned to the SEP, DCI, and CCC. Students use evidence and their content knowledge of how natural disasters have driven human migrations to construct an explanation in order to make a claim about how migration is caused by natural disasters.

Scoring Key

Part a

Correct Response:
The largest number of natural disasters occurred between [1985-1990, 1990-1995, **1995-2000**] which corresponded to a [**sharp increase**, slight increase, sharp decrease, slight decrease] in the rate of migration.

Part b

Correct Response: C

Distractor Rationales

Part b

A The Worldwide Natural Disasters graph shows the number of natural disasters is increasing, not decreasing.

B There is a correlation, but not enough evidence to claim causation. In addition, the Worldwide Migration graph shows different increases in migrants for different increases in number of disasters, which suggests that there are other factors of unknown importance.

C KEY: The graphs show that migration increases after natural disasters, which supports the claim because people who no longer have resources are more likely to migrate.

D The graphs can only support claims about migration continuing to increase because that is all the Worldwide Migration graph shows.

Item 15: PBT Standalone Item

Next Generation Science Standards Description

PE: HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

SEP: Constructing Explanations and Designing Solutions: Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

DCI: ESS3.B: Natural Hazards: Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

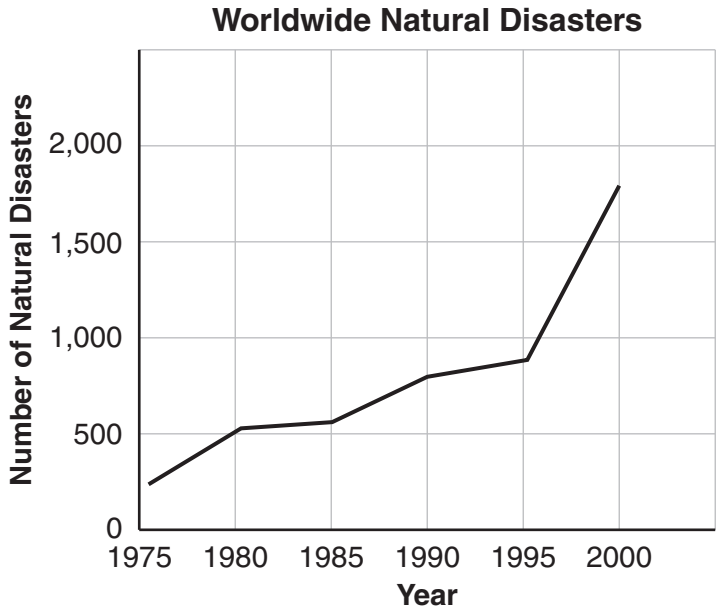
Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

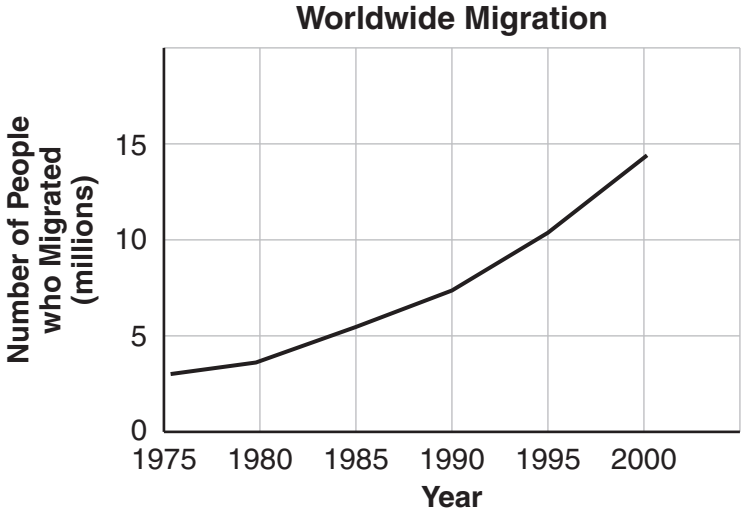
Item on next page

This item brings students into the story line by asking them to use evidence to construct an explanation about how the frequency of natural disasters has influenced human migration. The item aligns to the SEP by asking students to construct an explanation based on evidence. The item aligns to the DCI because students must use knowledge of how natural disasters have driven human migrations. The item aligns to the CCC because students must use evidence to make a claim about how migration is caused by natural disasters.

A student is studying the effects of climate change and natural disasters on human populations. The student finds a graph that shows the number of natural disasters between 1975 and 2000.



The student finds another graph that shows the number of people who migrated from low-income countries during the same time period.



The stimulus for this item begins by presenting the phenomenon that human populations have been influenced by climate change and natural disasters. The hook is that a student finds data on natural disasters and the number of people who migrate. The phenomenon and hook are grade-level appropriate because many students hear about natural disasters and human migrations on the news.

This question has two parts. Be sure to answer both parts of the question.

15. Part a

Which statement explains the trends shown in the graphs?

A The largest number of natural disasters occurred between 1980–1985, which corresponded to a slight decrease in the rate of migration.

B The largest number of natural disasters occurred between 1985–1990, which corresponded to a slight increase in the rate of migration.

C The largest number of natural disasters occurred between 1990–1995, which corresponded to a sharp decrease in the rate of migration.

D The largest number of natural disasters occurred between 1995–2000, which corresponded to a sharp increase in the rate of migration.

Part a is aligned to the SEP and CCC. Students construct an explanation using evidence and their understanding of the cause and effect relationship between migration and natural disasters.

Part b

Which claim about natural disasters is supported by the graphs?

A The number of natural disasters will decrease in the future.

B Natural disasters are the most important cause of migration.

C Natural disasters increase the difficulty of finding the resources needed to survive.

D The number of people who migrate will stop increasing as people become settled in their new country.

Part b is aligned to the SEP, DCI, and CCC. Students use evidence and their content knowledge of how natural disasters have driven human migrations to construct an explanation in order to make a claim about how migration is caused by natural disasters.

Scoring Key

Part a
Correct Response: D

Part b
Correct Response: C

Distractor Rationales

Part a

A Only around 500 natural disasters occurred during this time, and migration increased, not decreased, during this time.

B Even though migration increased during this time, the increase of between 500 and 1,000 natural disasters was not the largest.

C Around 800 natural disasters occurred in this time period, and migration increased, not decreased, during this time.

D KEY: The largest number of natural disasters (between 900 and 1,700) occurred during this time when migration increased sharply.

Part b

A The Worldwide Natural Disasters graph shows the number of natural disasters is increasing, not decreasing.

B There is a correlation, but not enough evidence to claim causation. In addition, the Worldwide Migration graph shows different increases in migrants for different increases in number of disasters, which suggests that there are other factors of unknown importance.

C KEY: The graphs show that migration increases after natural disasters, which supports the claim because people who no longer have resources are more likely to migrate.

D The graphs can only support claims about migration continuing to increase because that is all the Worldwide Migration graph shows.

Item 16: Standalone Item

Next Generation Science Standards Description

PE: HS-LS1-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [*Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.*]

SEP: Developing and Using Models: Use a model based on evidence to illustrate the relationships between systems or between components of a system.

DCI: LS1.C: Organization for Matter and Energy Flow in Organisms: As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

CCC: Energy and Matter: Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

Item Type: Open-ended

Cognitive Complexity: Stimulus-High | SEP-Med | DCI-Med | CCC-Med

Number of Points: 4

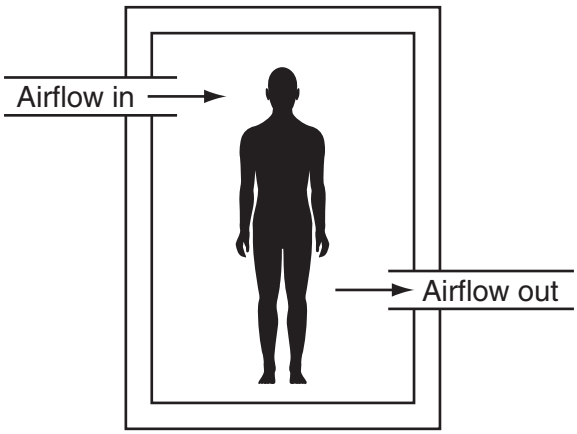
Item on next page

This item brings students into the story line by asking them to use a model to show how cellular respiration breaks bonds, forms new bonds, and transfers energy. The item aligns to the SEP by asking students to use a graphical model to describe the relationship between the content of air flowing into and out of a calorimeter room. The item aligns to the DCI because students must use knowledge of how cellular respiration breaks bonds, forms new bonds, and transfers energy in a human and to the environment. The item aligns to the CCC because students must use the understanding that energy is not created when cellular respiration releases stored energy.

Students learn that scientists have been investigating the source of energy that powers the human body for many years. They learn that scientists use special rooms called “calorimeter rooms” to measure the inputs and outputs of the human body in order to understand how cellular respiration produces energy used by the body.

Air is a mixture of gases. In the model shown in the diagram, air flows into and out of a calorimeter room.

Calorimeter Room Model



The stimulus for this item begins by presenting the phenomenon that energy powers the human body. The hook is that students learn that scientists measure human inputs and outputs in calorimeter rooms. The phenomenon and hook are grade-level appropriate because many students are interested in calories in food and how energy use is measured.

This question has three parts. Be sure to answer all three parts of the question.

16. **a.** Use the model to describe two differences between the air flowing into the room and the air flowing out of the room. Explain the reason for both differences.

b. Identify one input and one output of cellular respiration that are not described in part (a) and describe how to add both to the model.

c. Explain how cellular respiration releases stored energy that powers the human body.

Part a is aligned to the SEP and DCI. Students use the model and their content knowledge of how cellular respiration breaks bonds and forms new bonds to describe the relationship between the air flowing into and out of the calorimeter room.

Part b is aligned to the SEP and DCI. Students use and refine the model by using content knowledge of how cellular respiration breaks bonds, forms new bonds, and transfers energy.

Part c is aligned to the DCI and CCC. Students use their content knowledge of how cellular respiration breaks bonds, forms new bonds, and transfers energy to explain how cellular respiration releases stored energy.

Scoring Rubric

Score	Description
4	The response demonstrates thorough use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response describes two differences between the air flowing into the room and the air flowing out of the room and explains the reason for both differences. The response also identifies one input and one output of cellular respiration that are not described in part (a) and describes how to add these to the model. The response also explains how cellular respiration releases stored energy that powers the human body. The response • clearly applies science and engineering practices to provide an explanation or solution; • provides a coherent and accurate explanation or solution based on disciplinary core ideas; • reflects thorough understanding of complex ideas and crosscutting concepts; and • effectively applies and demonstrates complete understanding of the three dimensions.
3	The response demonstrates sufficient use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack some detail or information, or the response may contain minor errors in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
2	The response demonstrates limited use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack multiple details or information, or the response may contain major error(s) in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
1	The response demonstrates minimal use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
0	The response is inaccurate, is irrelevant, or contains no evidence of use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
Blank	No response

The scoring rubric specifies how a 4-point response uses the dimensions of the PE and provides detail about how different levels of response meet the requirements of specific tasks in the item. All open-ended standalone items are 4-point items.

Scoring Notes

a. Air flowing into the room has more oxygen than air flowing out of the room. Air flowing into the room has less carbon dioxide/water than air flowing out of the room. This is because cellular respiration uses up oxygen and produces carbon dioxide/water.

b. Inputs: energy, glucose/sugar/food Outputs: water (sweat)/carbon dioxide, energy (ATP)/thermal energy/heat. Inputs could be added with an arrow going toward the human. Outputs could be shown with an arrow going away from the human.

c. Cellular respiration breaks bonds in food and oxygen molecules and forms bonds in carbon dioxide and water. The bonds in the output molecules have less energy than the bonds in the input molecules and that energy is used for life.

The scoring notes provide information expected for a full credit/4-point response. They are written using the type of language most likely to be used by students.

Items 17–20: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

SEP: Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

DCI: PS3.B: Conservation of Energy and Energy Transfer:

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

DCI: PS3.D: Energy in Chemical Processes: Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

PE: HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

SEP: Using Mathematics and Computational Thinking: Create a computational model or simulation of a phenomenon, designed device, process, or system.

DCI: PS3.A: Definitions of Energy: 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.

DCI: PS3.B: Conservation of Energy and Energy Transfer:

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

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Cluster Overview: Mixing Liquids

Item	Item Type	Alignment
17	Multiple Choice	HS-PS3-4: SEP, CCC
18	Inline Choice	HS-PS3-1: DCI, CCC
18 PBT	Multiple Choice	HS-PS3-1: DCI, CCC
19	Multiple Choice—Multiple Choice	HS-PS3-4: SEP, DCI, CCC
20	Multiple Choice—Multiple Choice	HS-PS3-1: SEP, DCI, CCC

Stimulus and Items on next pages

The cluster consists of a phenomenon that allows overall item alignment across two PEs. While not every individual item in the cluster is three-dimensional, all items are at least two-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

Read the information. Then answer the questions that follow.

Mixing Liquids

On a hot summer day, a student makes lemonade by mixing lemon juice, sugar, and water. The student has no ice to chill his lemonade, so he mixes in cold lemon juice from the refrigerator with room temperature water and sugar. When he finishes mixing, the lemonade mixture is warmer than he expects. He adds even more cold lemon juice to make the mixture cooler, but this makes the lemonade much too sour to drink. The student decides to investigate how mixing different amounts of warm and cold liquids affects the final temperature of the mixture.

He learns that the amount of thermal energy transferred to or from a substance depends on the variables and relationships shown in the table.

Energy Transfer Equation

$Q = mc\Delta T$	Q = thermal energy transferred (in Joules) m = mass of substance (in grams) c = specific heat of substance (in J/g°C) ΔT = change in temperature of substance (in °C)

The student also learns that the specific heat of a substance is the amount of energy required to change the temperature of 1 g of the substance by 1°C. For example, water has a specific heat of 4.184 J/g°C, which means that the temperature of 1 g of water will change 1°C when 4.184 Joules (J) of energy are added to or removed from the water.

The stimulus for this item begins by presenting the phenomenon that mixing different amounts of hot and cold liquids affects the final temperature of the mixture. The hook is that a student tries to make cold lemonade using cold lemon juice and warm water and sugar. The phenomenon and hook are grade-level appropriate because many students have drunk lemonade and mixed liquids with different temperatures.

During his investigation, the student mixes several different masses and temperatures of water inside a closed system. His data are shown in the table.

Investigation Data

Mixture	Mass of Cold Water (g)	Temperature of Cold Water (°C)	Mass of Hot Water (g)	Temperature of Hot Water (°C)	Final Temperature of Mixture (°C)
1	20.0	20.0	80.0	50.0	43.0
2	40.0	18.0	60.0	52.0	37.0
3	75.0	22.0	25.0	60.0	31.0

Item 17: Cluster Item

Next Generation Science Standards Description

PE: HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

SEP: Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | CCC-Low

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to evaluate whether an investigation provides evidence that combining hot and cold water results in a transfer of thermal energy that distributes energy more uniformly in the system. The item aligns to the SEP by asking students to consider limitations on the data from the investigation. The item aligns to the CCC because students must use the understanding of inputs and outputs to the hot-cold water system during the investigation.

17. Which statement explains why the student's investigation produced low-quality data?

A The student used only three mixtures.

B The student used only water in the mixtures.

C The student changed many variables at the same time.

D The student did not use mixtures with a wide range of water temperatures.

This item is aligned to the SEP and CCC. Students evaluate limitations on the data in the investigation by using their understanding of the inputs and outputs to the lemonade system during the investigation.

Scoring Key

Correct Response: C

Distractor Rationales

A Three mixtures are enough if in those three mixtures each variable can be tested independently, which is not what happened in this experiment.

B Changing multiple variables, not using water for both the hot and cold liquids, makes this experiment valid.

C KEY: The experiment is invalid because many variables were changed in each mixture instead of only one independent variable being changed at a time.

D The investigation would be more valid if the water temperatures had been identical. Having a wide range of temperatures would make the data less, not more, valid.

Item 18: Cluster Item

Next Generation Science Standards Description

PE: HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

DCI: PS3.B: Conservation of Energy and Energy Transfer: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

CCC: Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Item Type: Inline Choice

Cognitive Complexity: Stimulus-Med | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to determine how energy flows from people to the water in a pool and to the air. The item aligns to the DCI because students must use knowledge of how energy is transferred between systems. The item aligns to the CCC because students must use the specific heat model to predict the flow of energy in the person-water and the water-air systems.

18. People who are outside on a hot day often cool off by going for a swim in a pool that is outside. Select the words to complete the statements that explain why a person could cool off in the pool.

The water temperature is cooler than the air temperature because water has a [higher, lower] specific heat than air. This means that when a person goes into the water, thermal energy flows [into, out of] the person's body.

This item is aligned to the DCI and CCC. Students use their content knowledge of how energy is transferred between systems and the specific heat model to predict the flow of energy in the person-water and the water-air systems.

Scoring Key

Correct Response:
The water temperature is cooler than the air temperature because water has a [**higher**, lower] specific heat than air. This means that when a person goes into the water, thermal energy flows [into, **out of**] the person's body.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 18: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

DCI: PS3.B: Conservation of Energy and Energy Transfer: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

CCC: Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to determine how energy flows from people to the water in a pool and to the air. The item aligns to the DCI because students must use knowledge of how energy is transferred between systems. The item aligns to the CCC because students must use the specific heat model to predict the flow of energy in the person-water and the water-air systems.

18. People who are outside on a hot day often cool off by going for a swim in a pool that is outside.

Which statement explains why a person could cool off in the pool?

A The water temperature is cooler than the air temperature because water has a lower specific heat than air. This means that when a person goes into the water, thermal energy flows into the person's body.

B The water temperature is cooler than the air temperature because water has a lower specific heat than air. This means that when a person goes into the water, thermal energy flows out of the person's body.

C The water temperature is cooler than the air temperature because water has a higher specific heat than air. This means that when a person goes into the water, thermal energy flows into the person's body.

D The water temperature is cooler than the air temperature because water has a higher specific heat than air. This means that when a person goes into the water, thermal energy flows out of the person's body.

This item is aligned to the DCI and CCC. Students use their content knowledge of how energy is transferred between systems and the specific heat model to predict the flow of energy in the person-water and the water-air systems.

Scoring Key

Correct Response: D

Distractor Rationales

A Water is cooler than air because more, not less, energy is needed to warm water to the same temperature as air. Thermal energy tends to flow into the colder water, not into the warmer person's body.

B If water had a lower specific heat than air, water would warm more quickly than air and be warmer, not cooler.

C Thermal energy flows from a warmer object (the person) to a colder object (the water).

D KEY: Water is cooler than air because more energy must be added to water than to air to increase the temperature by 1°C. Thermal energy naturally flows from warmer to colder objects.

Item 19: Cluster Item

Next Generation Science Standards Description

PE: HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

SEP: Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

DCI: PS3.B: Conservation of Energy and Energy Transfer: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

CCC: Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to refine an investigation so that the investigation provides evidence that combining hot and cold water results in a transfer of thermal energy that distributes energy more uniformly in the system. The item aligns to the SEP by asking students to decide how to collect data in a revised investigation. The item aligns to the DCI because students must use knowledge of how energy is transferred between systems. The item aligns to the CCC because students must define the boundaries and initial conditions of the hot-cold water system.

This question has two parts. Be sure to answer both parts of the question.

19. The student decides to repeat the investigation and collect new data.

Part a

Which change to the procedure will improve the quality of the data the student collects?

A Change only the mass of cold water in all the mixtures.

B Change both liquids to have the same mass and temperature in all the mixtures.

C Change the mass of cold water to be larger than the mass of hot water in all the mixtures.

D Change the temperature of cold water to be lower than the temperature of hot water in all the mixtures.

Part a is aligned to the SEP, DCI, and CCC. Students decide how to collect data in a revised investigation that can produce valid data by using their content knowledge of how energy is transferred between systems and by defining the boundaries and initial conditions of the hot-cold water system.

Part b

In addition to the change in Part (a), which variable should the student control during the investigation?

A the size of the container

B the final temperature of the mixture

C the mass of water in the final mixture

D the time to reach the final temperature

Part b is aligned to the SEP, DCI, and CCC. Students decide which variable to control in a revised investigation that can produce valid data by using their content knowledge of how energy is transferred between systems and by defining the boundaries and initial conditions of the hot-cold water system.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: A

Distractor Rationales

Part a

A **KEY: Changing only the mass of cold water would give the investigation only one independent variable.**

B This change would result in no independent variable.

C Whether there is more cold water or more hot water will not affect the quality of data.

D This is not a change to the procedure.

Part b

A **KEY: Keeping the container the same size will keep the amount of thermal energy that moves into air inside the container and (through surface area of the outside of the container) to the outside environment the same.**

B This cannot be controlled because this is the dependent variable.

C This cannot be controlled because different masses of cold water are required.

D This cannot be controlled because the time for different masses of water to reach the final temperature will be different.

Item 20: Cluster Item

Next Generation Science Standards Description

PE: HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

SEP: Using Mathematics and Computational Thinking: Create a computational model or simulation of a phenomenon, designed device, process, or system.

DCI: PS3.B: Conservation of Energy and Energy Transfer: 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.

CCC: Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-High | DCI-High | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to develop a computational model to calculate changes in energy when cold water and hot water are combined. The item aligns to the SEP by asking students to use a given equation and develop a computational model to calculate the changes in energy during the investigation. The item aligns to the DCI because students must use knowledge that a mathematical expression allows the use of conservation of energy to describe the behavior of a system. The item aligns to the CCC because students must use the mathematical model to predict the behavior of the hot-cold water system.

This question has two parts. Be sure to answer both parts of the question.

20. The student uses the equation and his data to calculate the amount of thermal energy transferred during his investigation.

NOTE: Part a of this item requires a calculator. Even though students will have access to a calculator during the assessment, items will not require the use of a calculator.

Part a

How much thermal energy is transferred into the cold water in mixture 1?

A 860 J

B 1,674 J

C 1,925 J

D 3,598 J

Part a is aligned to the SEP and DCI. Students use a mathematical equation and their content knowledge that the mathematical equation allows them to use conservation of energy by the system to calculate the change in energy in cold water during the investigation.

Part b

Which statement describes how the student could calculate how much thermal energy is transferred away from the liquids during his investigation?

A (thermal energy from cold liquid – thermal energy into hot liquid)

B (thermal energy from hot liquid – thermal energy into cold liquid)

C (thermal energy into cold liquid – thermal energy from hot liquid)

D (thermal energy into hot liquid – thermal energy from cold liquid)

Part b is aligned to the SEP, DCI, and CCC. Students use their content knowledge that the mathematical equation allows them to use conservation of energy to describe the behavior of the water-air system to develop a computational model that predicts the amount of energy transferred out of the hot-cold water system.

Scoring Key

Part a
Correct Response: C

Part b
Correct Response: B

Distractor Rationales

Part a

A The student forgot to multiply by 4.184 J/g•°C.

B The student multiplied by the initial temperature instead of by the change in temperature.

C KEY: The equation shows that 20 g x 4.184 J/g•°C x (43-20)°C = 1925 J.

D The student multiplied by the final temperature instead of by the change in temperature.

Part b

A Thermal energy does not move from a cold liquid into a hot liquid.

B KEY: This difference will be zero if no thermal energy is lost from the mixture to the environment.

C This is the reverse of the correct answer.

D Thermal energy moves from a hot liquid into a cold liquid.

Items 21–24: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: PS2.A: Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

PE: 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. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

SEP: Constructing Explanations and Designing Solutions: Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

DCI: PS2.A: Forces and Motion: If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

DCI: ETS1.A: Defining and Delimiting an Engineering Problem: Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

DCI: ETS1.C: Optimizing the Design Solution: Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

CCC: Cause and Effect: Systems can be designed to cause a desired effect.

Cluster Overview: Crumple Zones

Item	Item Type	Alignment
21	Multiple Choice—Multiple Choice	HS-PS2-3: SEP, DCI, CCC
22	Inline Choice	HS-PS2-1: SEP, DCI, CCC
22 PBT	Multiple Choice	HS-PS2-1: SEP, DCI, CCC
23	Multiple Choice—Multiple Choice	HS-PS2-1: SEP, DCI, CCC
24	Inline Choice	HS-PS2-3: SEP, DCI, CCC
24 PBT	Multiple Choice	HS-PS2-3: SEP, DCI, CCC

The cluster consists of a phenomenon that allows overall item alignment across two PEs. Every item in the cluster is three-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

Stimulus and Items on next pages

Read the information. Then answer the questions that follow.

Crumple Zones

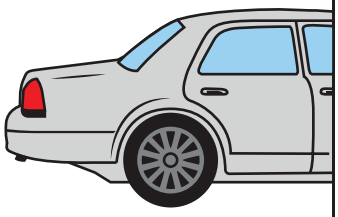
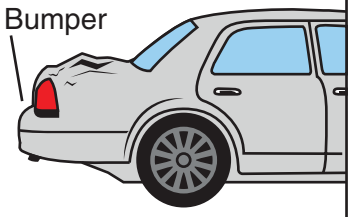
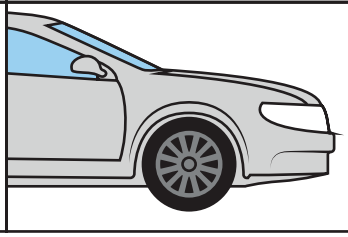
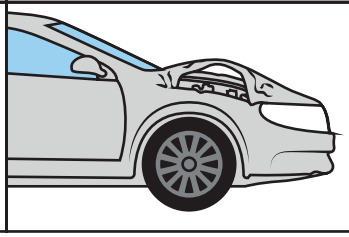
While driving to school, a student passes a car that backed out of a parking space and into a wall. The student observes that even though the car was moving slowly, the rear bumper of the car was damaged. She wonders why the bumper was damaged by a low-speed collision. She decides to investigate.

The student is surprised to learn that cars are designed to be damaged during collisions. When cars were first built, they were designed to be undamaged by collisions. However, people soon realized that when cars were not damaged during collisions, the people inside them were. So cars were redesigned to increase damage to the car in order to decrease damage to the people inside the car.

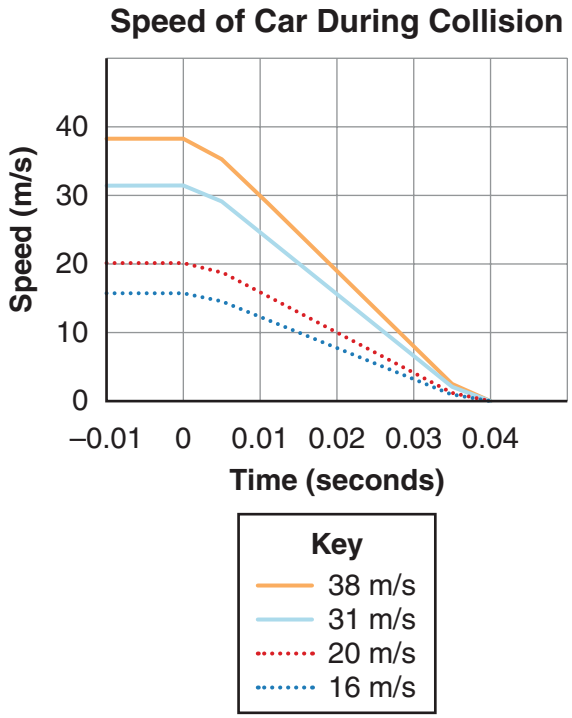
To understand this, the student learns that cars are designed with crumple zones at the front and rear ends of the car that reduce the force on a car during a collision. The diagram shows how a collision can affect the crumple zones at the ends of a car.

The stimulus for this cluster begins by presenting the phenomenon that bumpers are designed to be damaged. The hook is that a student observes that a car bumper is damaged during a low speed collision. The phenomenon and hook are grade-level appropriate because many students have observed cars that have been damaged during collisions.

Crumple Zones

Part of Car	Before Collision	After Collision
Rear		
Front		

The student starts to think about how Newton's laws of motion affect the forces on a car during a collision. She finds data from a scientific study in which researchers measured the speed of a car during a collision that stopped the car. The researchers used the same car moving with four different speeds before each collision. The graph shows how the speed of the car changed during each collision.



Item 21: Cluster Item

Next Generation Science Standards Description

PE: 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. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

SEP: Constructing Explanations and Designing Solutions: Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

DCI: PS2.A: Forces and Motion: If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

CCC: Cause and Effect: Systems can be designed to cause a desired effect.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to apply scientific and engineering ideas to evaluate how well a bumper minimizes the force on a car during a collision. The item aligns to the SEP by asking students to apply scientific ideas to the design of a car bumper. The item aligns to the DCI because students must use knowledge of changes in momentum during a collision. The item aligns to the CCC because students must explain how bumpers are designed to cause the desired effect.

This question has two parts. Be sure to answer both parts of the question.

21. Part a

What caused the damage that the student observed on the rear bumper of the car that backed into the wall?

A The bumper had momentum before the collision but not after the collision.

B The wall changed the momentum of the car by exerting a force on the car.

C The bumper exerted a force on the wall before the rest of the car hit the wall.

D The wall exerted more force on the bumper than the bumper exerted on the wall.

Part a is aligned to the SEP, DCI, and CCC. Students apply scientific ideas to a car bumper by using their content knowledge of changes in momentum during a collision to explain what causes the damage that bumpers are designed to receive during a collision.

Part b

How did the crumple zone on the rear bumper decrease the force on the car during the collision with the wall?

A The crumple zone increased the speed of the car.

B The crumple zone increased the car's acceleration.

C The crumple zone increased the momentum of the car.

D The crumple zone increased the time for the car to stop.

Part b is aligned to the SEP, DCI, and CCC. Students apply scientific ideas to the design of a car bumper by using their content knowledge of changes in momentum during a collision to explain how bumpers are designed to minimize force during a collision.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: D

Distractor Rationales

Part a

A The damage was not caused by a change in momentum.

B KEY: Changing momentum requires a force and this force caused the damage.

C The car was damaged because the wall exerted a force on the bumper, which happened at the same time, not after, the bumper exerted a force on the wall.

D The forces were equal in size and the car was damaged because both forces were equally large.

Part b

A The crumple zone decreased the force by decreasing how quickly the speed changed, not by increasing the speed.

B The crumple zone decreased, not increased, the car's acceleration.

C The crumple zone decreased, not increased, the car's momentum.

D KEY: Force was decreased by changing the car's momentum more slowly.

Item 22: Cluster Item

Next Generation Science Standards Description

PE: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: PS2.A: Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Inline Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to analyze data to support a claim about the mathematical relationship between the force on a car and the car's acceleration. The item aligns to the SEP by asking students to analyze data in a graph in order to make a claim. The item aligns to the DCI because students must use knowledge of how Newton's second law predicts changes in the motion of a car. The item aligns to the CCC because students must use evidence to make a claim about how the time for the car's motion to change affects the amount of force on the car.

22. The student wonders how the data in the graph would be different if the car had taken twice as much time to stop during the collision.

Select the words that describe a claim that is supported by the graph.

Increasing the time for the car to stop would have [increased, decreased] the acceleration of the car and [increased, decreased] the force on the car.

This item is aligned to the SEP, DCI, and CCC. Students analyze data in order to make a claim by using their content knowledge of how Newton's second law predicts changes in motion and the cause and effect relationship between the time needed to stop the car, the acceleration of the car, and the force on the car.

Scoring Key

Correct Response:
Increasing the time for the car to stop would have [increased, **decreased**] the acceleration of the car and [increased, **decreased**] the force on the car.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 22: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: PS2.A: Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to analyze data to support a claim about the mathematical relationship between the force on a car and the car's acceleration. The item aligns to the SEP by asking students to analyze data in a graph in order to make a claim. The item aligns to the DCI because students must use knowledge of how Newton's second law predicts changes in the motion of a car. The item aligns to the CCC because students must use evidence to make a claim about how the time for the car's motion to change affects the amount of force on the car.

22. The student wonders how the data in the graph would be different if the car had taken twice as much time to stop during the collision.

Which claim is supported by the graph?

A Increasing the time for the car to stop would have decreased the acceleration of the car and decreased the force on the car.

B Increasing the time for the car to stop would have decreased the acceleration of the car and increased the force on the car.

C Increasing the time for the car to stop would have increased the acceleration of the car and increased the force on the car.

D Increasing the time for the car to stop would have increased the acceleration of the car and decreased the force on the car.

This item is aligned to the SEP, DCI, and CCC. Students analyze data in order to make a claim by using their content knowledge of how Newton's second law predicts changes in motion and the cause and effect relationship between the time needed to stop the car, the acceleration of the car, and the force on the car.

Scoring Key

Correct Response: A

Distractor Rationales

A **KEY: If the car used more time to stop, the car's acceleration would decrease, and since this would decrease force exerted by the car, the force exerted on the car would also decrease.**

B If the car's acceleration decreased, the force exerted by the car would be less and the force exerted on the car would be less, not more.

C Using more time to stop would decrease, not increase, the acceleration and therefore decrease, not increase, the forces during the collision.

D Using more time to stop would decrease, not increase, acceleration because the change in speed happens over a longer time.

Item 23: Cluster Item

Next Generation Science Standards Description

PE: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

SEP: Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

DCI: PS2.A: Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-High | DCI-High | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to analyze data to support a claim about the mathematical relationship between a car's speed and the force on the car. The item aligns to the SEP by asking students to analyze data about a car's speed and acceleration to make a claim. The item aligns to the DCI because students must use knowledge of Newton's second law to predict a change in the motion of a car. The item aligns to the CCC because students must use evidence to make a claim about how speed affects the acceleration of a car and the force needed to stop the car.

This question has two parts. Be sure to answer both parts of the question.

23. The student studies the graph that shows how the speed of a car changes during a collision.

Part a

Which claim is supported by the data in the graph?

A More force is needed to stop a car that has less mass.

B More force is needed to stop a car that has more mass.

C More force is needed to stop a car that has less speed.

D More force is needed to stop a car that has more speed.

Part a is aligned to the SEP, DCI, and CCC. Students analyze data in order to make a claim by using their content knowledge of how Newton's second law predicts changes in motion and by using the data as evidence of how speed affects the force needed to stop a car.

Part b

Which evidence in the graph supports the claim in Part (a)?

A Cars that were moving faster before the collision accelerated more during the collision.

B Cars that were moving slower before the collision stopped more quickly during the collision.

C Cars that changed speed less during the collision had more acceleration during the collision.

D Cars that changed speed more during the collision took more time to stop during the collision.

Part b is aligned to the SEP, DCI, and CCC. Students analyze data to determine which data support the claim by using content knowledge of how Newton's second law predicts changes in motion and by using the data as evidence of how speed affects the acceleration of the car and the force needed to stop a car.

Scoring Key

Part a
Correct Response: D

Part b
Correct Response: A

Distractor Rationales

Part a

A The graph shows data for one car with different speeds, not different masses.

B This claim is not supported by the graph which has data for only one car with one mass.

C The graph shows that when the car was moving at the slowest speed, the acceleration was smallest and so the car was stopped by the least, not the most, force.

D KEY: The graph shows that when the car was moving at the highest speed, the acceleration was largest (most change in speed in same time) which would have been caused by the largest force.

Part b

A KEY: The graph shows that the rate of change of speed (the acceleration, the slope of the line) increased as speed increased: more force caused the speed to change more quickly. In this graph, the slope is negative, the change in speed is negative, and the acceleration is negative because speed is decreasing during the collision.

B The graph shows that the car took the same amount of time to stop, no matter the speed of the car.

C A larger, not smaller, change in speed would result in more acceleration.

D The graph shows that the car took 0.04 seconds to stop, no matter how fast the car was moving.

Item 24: Cluster Item

Next Generation Science Standards Description

PE: 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. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

SEP: Constructing Explanations and Designing Solutions: Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

DCI: PS2.A: Forces and Motion: If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

CCC: Cause and Effect: Systems can be designed to cause a desired effect.

Item Type: Inline Choice

Cognitive Complexity: Stimulus-Med | SEP-Low | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to apply scientific ideas to explain how seat belts and air bags protect people by minimizing the force on people during a collision. The item aligns to the SEP by asking students to apply scientific ideas to the design of seat belts and air bags. The item aligns to the DCI because students must use knowledge of changes in momentum during a collision. The item aligns to the CCC because students must evaluate how seat belts and air bags are designed to cause the desired effect.

24. Engineers design cars with crumple zones to protect people inside cars. They have also added seat belts and air bags to protect people.

Select the words that describe how seat belts and air bags protect people during collisions.

Seat belts and air bags [increase, decrease] the force on people during a collision by [increasing, decreasing] the time for the people to stop.

Scoring Key

Correct Response:
Seatbelts and air bags [increase, **decrease**] the force on people during a collision by [**increasing**, decreasing] the time for the people to stop.

This item is aligned to the SEP, DCI, and CCC. Students apply scientific ideas to evaluate the design of seat belts and air bags by using their content knowledge of changes in momentum during a collision to explain how seat belts and air bags are designed to decrease the force on people during a collision.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 24: PBT Cluster Item

Next Generation Science Standards Description

PE: 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. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

SEP: Constructing Explanations and Designing Solutions: Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.

DCI: PS2.A: Forces and Motion: If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

CCC: Cause and Effect: Systems can be designed to cause a desired effect.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Low | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to apply scientific ideas to explain how seat belts and air bags protect people by minimizing the force on people during a collision. The item aligns to the SEP by asking students to apply scientific ideas to the design of seat belts and air bags. The item aligns to the DCI because students must use knowledge of changes in momentum during a collision. The item aligns to the CCC because students must evaluate how seat belts and air bags are designed to cause the desired effect.

24. Engineers design cars with crumple zones to protect people inside cars. They have also added seat belts and air bags to protect people.

Which statement describes how seat belts and air bags protect people during collisions?

A Seat belts and air bags decrease the force on people during a collision by increasing the time for the people to stop.

B Seat belts and air bags decrease the force on people during a collision by decreasing the time for the people to stop.

C Seat belts and air bags increase the force on people during a collision by decreasing the time for the people to stop.

D Seat belts and air bags increase the force on people during a collision by increasing the time for the people to stop.

This item is aligned to the SEP, DCI, and CCC. Students apply scientific ideas to evaluate the design of seat belts and air bags by using their content knowledge of changes in momentum during a collision to explain how seat belts and air bags are designed to decrease the force on people during a collision.

Scoring Key

Correct Response: A

Distractor Rationales

A **KEY: Seat belts and air bags decrease force by decreasing acceleration. This is done by increasing the time needed to stop.**

B Seat belts and air bags decrease force by increasing, not decreasing, the time for the people to stop.

C Seat belts and air bags decrease, and do not increase, the force on people during a collision by increasing, not decreasing, the time for the people to stop. Increasing the force would not protect people.

D Seat belts and air bags decrease, and do not increase, the force on people during a collision. Increasing the force would protect people less, not more.

Session 3: Items 25–37

Item 25: Standalone Item

Next Generation Science Standards Description

PE: HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [*Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.*]

SEP: Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

DCI: LS1.A: Structure and Function: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

CCC: Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-High | SEP-Med | DCI-High | CCC-High

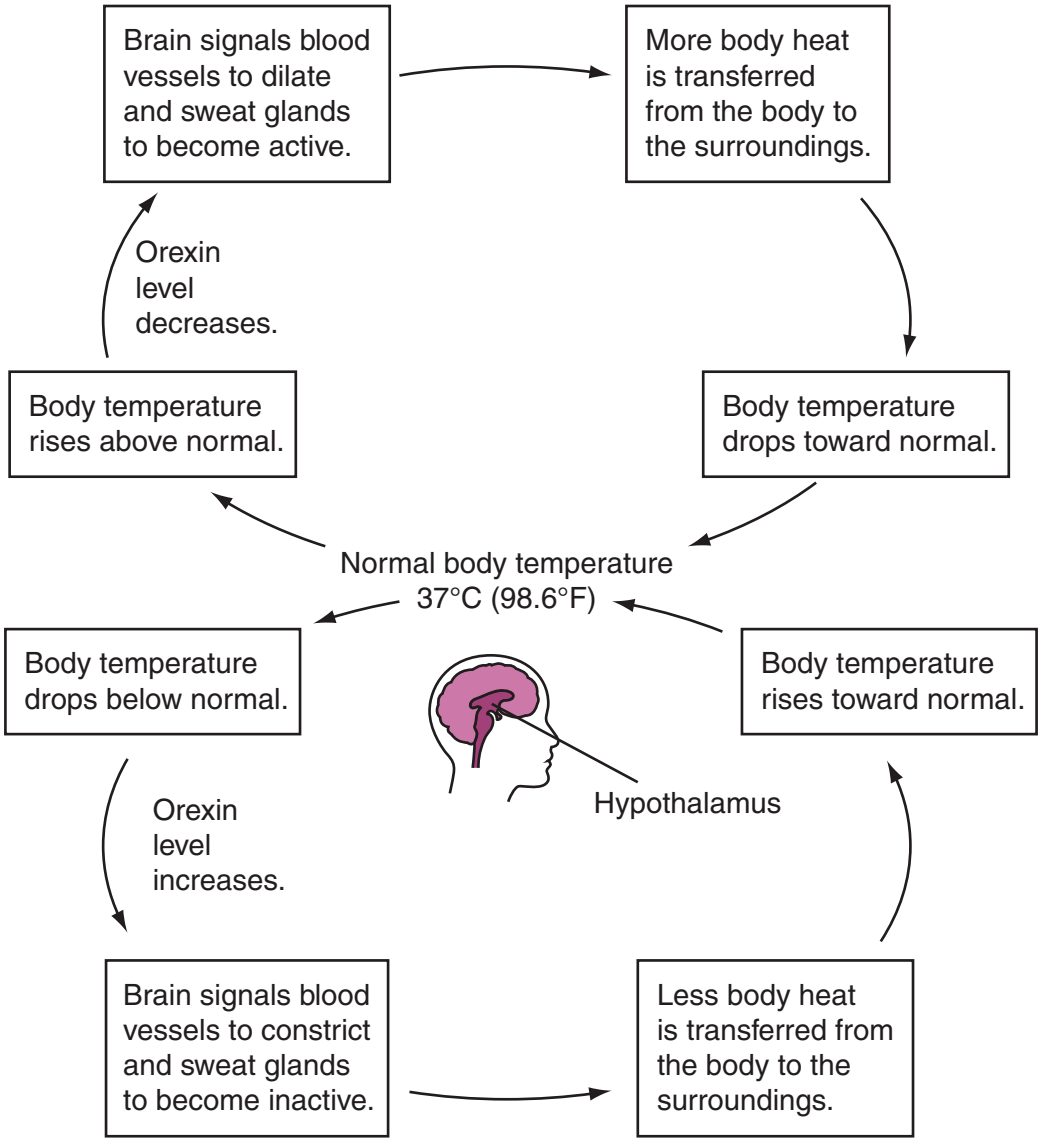
Number of Points: 2

Item on next page

This item brings students into the story line by asking them to plan an investigation to provide evidence that feedback mechanisms involving orexin help maintain body temperature. The item aligns to the SEP by asking students to plan an investigation to produce data that can be evidence of the temperature feedback mechanism. The item aligns to the DCI because students must use knowledge of how feedback mechanisms maintain a living system's internal conditions. The item aligns to the CCC because students must use understanding that feedback can stabilize body temperature.

A research group is studying the effects of orexin, a neurotransmitter that is produced in the hypothalamus. Because orexin is known to regulate many processes, the group wants to investigate whether orexin helps maintain body temperature in the way shown in the diagram.

Maintaining Body Temperature



The stimulus for this item begins by presenting the phenomenon that a neurotransmitter regulates many bodily processes. The hook is that a research group wants to investigate whether orexin helps maintain body temperature. The phenomenon and hook are grade-level appropriate because students may have wondered about the internal processes that keep their bodies from becoming too warm or cool.

This question has two parts. Be sure to answer both parts of the question.

25. Part a

Which procedure could provide evidence that orexin has the effects shown in the diagram?

A comparing body temperatures of active individuals who produce normal and low levels of orexin

B comparing body temperatures of resting individuals who produce normal and low levels of orexin

C comparing body temperatures of active individuals and resting individuals who produce low levels of orexin

D comparing body temperatures of active individuals and resting individuals who produce normal levels of orexin

Part a is aligned to the SEP, DCI, and CCC. Students decide how to plan an investigation that collects data that can be evidence of the temperature feedback mechanism by using their content knowledge of how feedback mechanisms maintain a living system's internal conditions and their understanding of how feedback involving orexin stabilizes the system.

Part b

Which type of feedback is shown in both loops in the diagram?

A The loops show positive feedback because changes in orexin levels are beneficial to body temperature.

B The loops show positive feedback because orexin level increases when body temperature increases.

C The loops show negative feedback because changes in orexin levels result in normal body temperature.

D The loops show negative feedback because orexin level decreases when body temperature decreases.

Part b is aligned to the DCI and CCC. Students use their content knowledge of how feedback mechanisms maintain a living system's internal conditions to describe how feedback involving orexin stabilizes body temperature.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: C

Distractor Rationales

Part a

A **KEY: This step in an investigation would allow researchers to determine whether orexin is able to keep body temperature from changing.**

B Resting individuals do not need the feedback loop to maintain body temperature (unless they are in a very cold place).

C This procedure would not show how orexin maintains body temperature because without different levels of orexin, there is no evidence of a feedback loop.

D This procedure would not show how orexin maintains body temperature because there is no information about how body temperature is affected by different levels of orexin.

Part b

A Positive feedback is not necessarily beneficial and the diagram shows negative feedback that maintains a stable body temperature.

B While this would be positive feedback, the diagram shows that the orexin level decreases, and does not increase, when body temperature increases.

C **KEY: This statement describes negative feedback and is shown in the diagram.**

D While this would be negative feedback, the diagram shows that when body temperature decreases, the orexin level increases.

Item 26: Standalone Item

Next Generation Science Standards Description

PE: HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [*Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical or computational representations of phenomena to describe explanations.

DCI: ESS1.B: Earth and the Solar System: Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

CCC: Scale, Proportion, and Quantity: Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Item Type: Inline Choice—Inline Choice

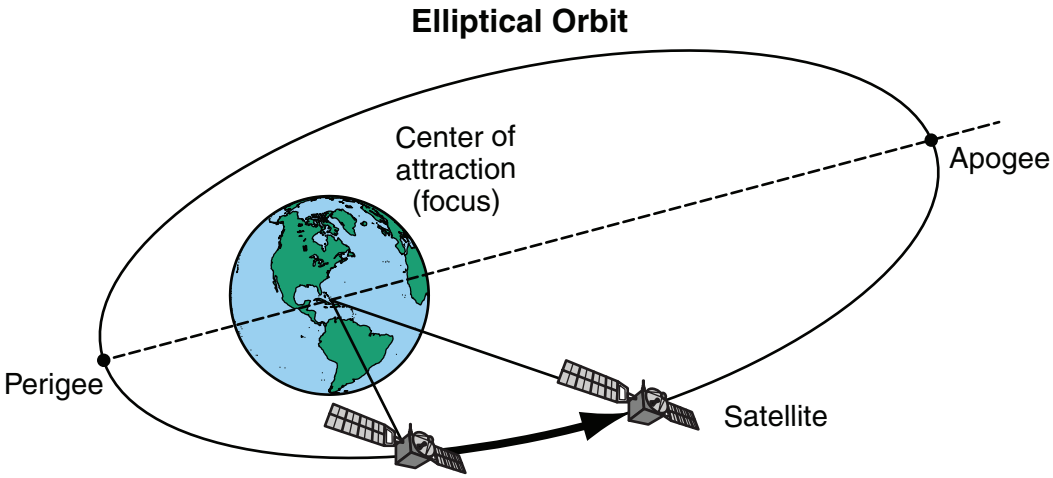
Cognitive Complexity: Stimulus-Med | SEP-Low | DCI-High | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use a mathematical representation to predict the motion of a satellite orbiting Earth in a specific orbit. The item aligns to the SEP by asking students to use mathematical representations to explain changes in speed during an orbit. The item aligns to the DCI because students must use knowledge of how Kepler's laws and gravitational effects describe the motions of objects in elliptical orbits. The item aligns to the CCC because students must use algebraic thinking to predict the effect of a change in one variable on another.

Astronomers want to send a satellite into the elliptical orbit around Earth that is shown in the diagram.



The stimulus for this item begins by presenting the phenomenon that satellites orbit Earth in an elliptical orbit. The hook is that astronomers want to put a satellite into a specific orbit. The phenomenon and hook are grade-level appropriate because many students may hear about satellite launches in the news.

NOTE: This item requires students to use Kepler's laws. On the assessment, items that require use of Kepler's laws will provide the laws in the stimulus.

This question has two parts. Be sure to answer both parts of the question.

26. Part a

Select the words that describe the speed of the satellite in the orbit shown in the diagram.

The speed is largest at [perigee, apogee] and smallest at [perigee, apogee].

Part b

Select the words that describe the reason for the answer to Part (a).

The satellite moves fastest where the force of Earth's gravity is [largest, smallest].

The satellite has the largest acceleration when the satellite is at [perigee, apogee].

Scoring Key

Part a
Correct Response:
The speed is largest at [**perigee**, apogee] and smallest at [perigee, **apogee**].

Part b
Correct Response:
The satellite moves fastest where the force of Earth's gravity is [**largest**, smallest].
The satellite has the largest acceleration when the satellite is at [**perigee**, apogee].

Part a is aligned to the SEP, DCI, and CCC. Students use the mathematical representations in Kepler's laws, their content knowledge of how Kepler's laws describe the motions of objects in elliptical orbits, and algebraic thinking to predict the effect of distance from Earth on the speed of a satellite.

Part b is aligned to the SEP, DCI, and CCC. Students use the mathematical representations in Kepler's laws, their content knowledge of how gravitational effects change the motions of objects in elliptical orbits, and algebraic thinking to predict the effect of distance from Earth on the force on a satellite and the acceleration of the satellite.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 26: PBT Standalone Item

Next Generation Science Standards Description

PE: HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [*Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical or computational representations of phenomena to describe explanations.

DCI: ESS1.B: Earth and the Solar System: Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

CCC: Scale, Proportion, and Quantity: Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Item Type: Multiple Choice—Multiple Choice

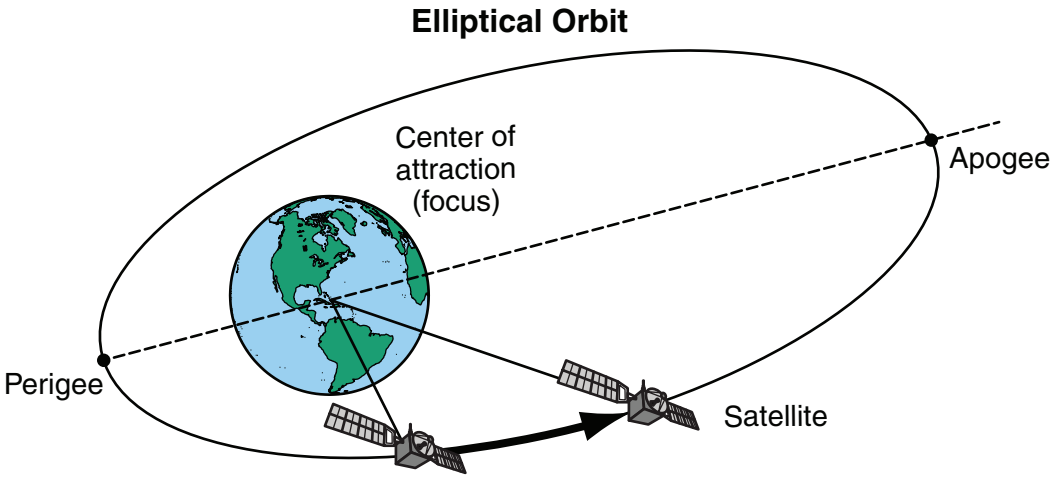
Cognitive Complexity: Stimulus-Med | SEP-Low | DCI-High | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use a mathematical representation to predict the motion of a satellite orbiting Earth in a specific orbit. The item aligns to the SEP by asking students to use mathematical representations to explain changes in speed during an orbit. The item aligns to the DCI because students must use knowledge of how Kepler's laws and gravitational effects describe the motions of objects in elliptical orbits. The item aligns to the CCC because students must use algebraic thinking to predict the effect of a change in one variable on another.

Astronomers want to send a satellite into the elliptical orbit around Earth that is shown in the diagram.



The stimulus for this item begins by presenting the phenomenon that satellites orbit Earth in an elliptical orbit. The hook is that astronomers want to put a satellite into a specific orbit. The phenomenon and hook are grade-level appropriate because many students may hear about satellite launches in the news.

NOTE: This item requires students to use Kepler's laws. On the assessment, items that require use of Kepler's laws will provide the laws in the stimulus.

This question has two parts. Be sure to answer both parts of the question.

26. Part a

Which statement describes the speed of the satellite in the orbit shown in the diagram?

A The speed of the satellite is smallest at perigee and largest at apogee.

B The speed of the satellite is smallest between perigee and apogee.

C The speed of the satellite is largest at perigee and smallest at apogee.

D The speed of the satellite is largest directly before perigee and apogee.

Part a is aligned to the SEP, DCI, and CCC. Students use the mathematical representations in Kepler's laws, their content knowledge of how Kepler's laws describe the motions of objects in elliptical orbits, and algebraic thinking to predict the effect of distance from Earth on the speed of a satellite.

Part b

Which statement describes the reason for the answer to Part (a)?

A The satellite moves fastest where the force of Earth's gravity is largest, and the satellite has the largest acceleration when the satellite is at perigee.

B The satellite moves fastest where the force of Earth's gravity is largest, and the satellite has the largest acceleration when the satellite is at apogee.

C The satellite moves fastest where the force of Earth's gravity is smallest, and the satellite has the largest acceleration when the satellite is at perigee.

D The satellite moves fastest where the force of Earth's gravity is smallest, and the satellite has the largest acceleration when the satellite is at apogee.

Part b is aligned to the SEP, DCI, and CCC. Students use the mathematical representations in Kepler's laws, their content knowledge of how gravitational effects change the motions of objects in elliptical orbits, and algebraic thinking to predict the effect of distance from Earth on the force on a satellite and the acceleration of the satellite.

Scoring Key

Part a
Correct Response: C

Part b
Correct Response: A

Distractor Rationales

Part a

A The speed of the satellite is largest, not smallest, at perigee and smallest, not largest at apogee.

B The speed of the satellite is smallest at apogee, when the satellite is farthest from Earth.

C KEY: The speed of the satellite is largest at perigee because at this position the satellite is closest to Earth and the force of gravity is strongest. As the satellite moves farther from Earth, speed decreases and is a minimum at apogee.

D The speed of the satellite is largest at perigee, when the satellite is closest to Earth.

Part b

A KEY: Earth's gravity causes the satellite to move faster as the satellite moves toward Earth. As the satellite moves toward perigee, the force of gravity increases and so does the satellite's acceleration.

B The satellite is moving away from Earth toward apogee, and the gravitational force, and therefore the acceleration, is decreasing. At apogee, the acceleration and force are smallest, not largest.

C At perigee, the satellite is closest to Earth and both the gravitational force and acceleration are largest, not smallest.

D Earth's gravitational force is smallest at apogee where the satellite is moving slowest, not fastest, and has the smallest, not largest, acceleration.

Item 27: Standalone Item

Next Generation Science Standards Description

PE: HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical or computational representations of phenomena to describe explanations.

DCI: PS4.A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Inline Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use mathematical thinking to support claims about the relationships among the frequency, wavelength, and speed of sound waves traveling in steel and in air. The item aligns to the SEP by asking students to use mathematical thinking and the wave equation to explain changes in wavelength and frequency. The item aligns to the DCI because students must use knowledge of how the wavelength, frequency, and speed of waves are affected by the medium the wave travels through. The item aligns to the CCC because students must make claims about how changes in medium affect wavelength and frequency.

This question has two parts. Be sure to answer both parts of the question.

27. While watching an old movie, a student sees an actor putting his ear on the steel rail of a railroad track to listen for the train coming down the tracks. She is surprised that the actor with his ear to the rail hears the sound of the wheels before the other actors standing next to him hear the sound of the wheels.

The student investigates and finds that the speed of sound waves in a medium depends on the arrangement of particles in the medium. She finds that the speed of sound waves in steel is almost 17 times the speed of sound waves in air.

Part a

Select the phrases that describe the sound waves made by the train wheels.

The wavelength of sound waves in steel is [17 times longer than, 17 times shorter than, the same as] the wavelength of sound waves in air.

The frequency of sound waves in steel is [17 times longer than, 17 times shorter than, the same as] the frequency of sound waves in air.

Part b

Which relationship explains the answer to Part (a)?

A The speed of a wave is wavelength divided by frequency.

B The speed of a wave is the sum of wavelength plus frequency.

C The speed of a wave is the product of wavelength times frequency.

D The speed of a wave is the difference of frequency minus wavelength.

The stimulus for this item begins by presenting the phenomenon that sound travels faster through steel than air. The hook is that a student is surprised by this phenomenon while watching a movie and decides to investigate. The phenomenon and hook are grade-level appropriate because many students watch movies and they may become curious about scientific phenomena in the movies.

Part a is aligned to the SEP, DCI and CCC. Students use mathematical thinking and the wave equation and their content knowledge of how the wavelength, frequency, and speed of a wave is affected by the medium the wave travels through to make a claim that changes in medium affect wavelength and frequency.

Part b is aligned to the SEP and DCI. Students use their content knowledge of how the wavelength, frequency, and speed of a wave is affected by the medium the wave travels through to identify the mathematical relationship that explains how wavelength and frequency are affected by changes in wave speed.

Scoring Key

Part a

Correct Response:
The wavelength of sound waves in steel is [**17 times longer than**, 17 times shorter than, the same as] the wavelength of sound waves in air.

The frequency of sound waves in steel is [17 times longer than, 17 times shorter than, **the same as**] the frequency of sound waves in air.

Part b

Correct Response: C

Distractor Rationales

Part b

A Speed is wavelength times, not divided by, frequency.

B The speed is found by multiplying, not adding, wavelength and frequency.

C KEY: The speed of a wave is wavelength times frequency.

D The speed is the product of, not the difference between, wavelength and frequency.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 27: PBT Standalone Item

Next Generation Science Standards Description

PE: HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]

SEP: Using Mathematics and Computational Thinking: Use mathematical or computational representations of phenomena to describe explanations.

DCI: PS4.A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use mathematical thinking to support claims about the relationships among the frequency, wavelength, and speed of sound waves traveling in steel and in air. The item aligns to the SEP by asking students to use mathematical thinking and the wave equation to explain changes in wavelength and frequency. The item aligns to the DCI because students must use knowledge of how the wavelength, frequency, and speed of waves are affected by the medium the wave travels through. The item aligns to the CCC because students must make claims about how changes in medium affect wavelength and frequency.

This question has two parts. Be sure to answer both parts of the question.

27. While watching an old movie, a student sees an actor putting his ear on the steel rail of a railroad track to listen for the train coming down the tracks. She is surprised that the actor with his ear to the rail hears the sound of the wheels before the other actors standing next to him hear the sound of the wheels.

The student investigates and finds that the speed of sound waves in a medium depends on the arrangement of particles in the medium. She finds that the speed of sound waves in steel is almost 17 times the speed of sound waves in air.

The stimulus for this item begins by presenting the phenomenon that sound travels faster through steel than air. The hook is that a student is surprised by this phenomenon while watching a movie and decides to investigate. The phenomenon and hook are grade-level appropriate because many students watch movies and they may become curious about scientific phenomena in the movies.

Part a

Which statement describes the sound waves made by the train wheels?

A The wavelength of sound waves in steel is the same as the wavelength of sound waves in air, and the frequency of sound waves in steel is 17 times longer than the frequency of sound waves in air.

B The wavelength of sound waves in steel is the same as the wavelength of sound waves in air, and the frequency of sound waves in steel is 17 times shorter than the frequency of sound waves in air.

C The wavelength of sound waves in steel is 17 times shorter than the wavelength of sound waves in air, and the frequency of sound waves in steel is the same as the frequency of sound waves in air.

D The wavelength of sound waves in steel is 17 times longer than the wavelength of sound waves in air, and the frequency of sound waves in steel is the same as the frequency of sound waves in air.

Part a is aligned to the SEP, DCI and CCC. Students use mathematical thinking and the wave equation and their content knowledge of how the wavelength, frequency, and speed of a wave is affected by the medium the wave travels through to make a claim that changes in medium affect wavelength and frequency.

Part b

Which relationship explains the answer to Part (a)?

A The speed of a wave is wavelength divided by frequency.

B The speed of a wave is the sum of wavelength plus frequency.

C The speed of a wave is the product of wavelength times frequency.

D The speed of a wave is the difference of frequency minus wavelength.

Part b is aligned to the SEP and DCI. Students use their content knowledge of how the wavelength, frequency, and speed of a wave is affected by the medium the wave travels through to identify the mathematical relationship that explains how wavelength and frequency are affected by changes in wave speed.

Scoring Key

Part a
Correct Response: D

Part b
Correct Response: C

Distractor Rationales

Part a

A The wavelength, not the frequency, changes when a wave enters a different medium.

B The wavelength will be longer, not the same, in steel because the waves travel faster and the frequency will stay the same, not increase.

C Wavelength increases when waves travel faster and move farther in the same amount of time so wavelength will be longer, not shorter, in steel.

D KEY: Since wavelength times frequency equals the speed of the sound wave, and the frequency stays the same, the wavelength of sound waves in steel must be 17 times longer than the wavelength of sound waves in air.

Part b

A Speed is wavelength times, not divided by, frequency.

B The speed is found by multiplying, not adding, wavelength and frequency.

C KEY: The speed of a wave is wavelength times frequency.

D The speed is the product of, not the difference between, wavelength and frequency.

Item 28: Standalone Item

Next Generation Science Standards Description

PE: HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

SEP: Engaging in Argument From Evidence: Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.

DCI: LS4.C: Adaptation: Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to evaluate the evidence supporting claims that differences in the number of predators results in genetic changes in guppies that could result in the emergence of a new species over time. The item aligns to the SEP by asking students to evaluate whether claims are supported by evidence. The item aligns to the DCI because students must use knowledge of how changes in the physical environment may cause populations to diverge and possibly become new distinct species. The item aligns to the CCC because students must use evidence to evaluate whether rapid genetic changes are caused by rapid rates of reproduction.

This question has two parts. Be sure to answer both parts of the question.

28. A student reads about a scientist who is investigating how an environmental change affects a population of guppies, a species of small fish. In the investigation, the scientist moves guppies from a stream ecosystem that includes predators to a stream ecosystem without predators.

After a year, the scientist collects guppies from both streams and compares their DNA. She finds differences in 135 genes related to metabolism, immune function, and development.

The stimulus for this item begins by presenting the phenomenon that an environmental change (absence of predators) can cause genetic changes in a population over time. The hook is that a student is reading about a scientific investigation that found genetic differences between guppies in geographically isolated populations. The phenomenon and hook are grade-level appropriate because many students are familiar with guppies, predators, and genetic changes.

Part a

The student claims that guppies were chosen for the investigation because they reproduce rapidly.

Which statement describes the student's claim?

A The claim is valid because genetic changes occur more quickly in individuals than in populations.

B The claim is valid because genetic changes in a population can appear after several generations.

C The claim is not valid because genetic changes require millions of years to spread throughout a population.

D The claim is not valid because genetic changes in a population are caused by environmental changes, not by reproduction.

Part a is aligned to the SEP, DCI and CCC. Students evaluate whether evidence supports a claim by using their content knowledge of how changes in the physical environment may cause populations to diverge to evaluate whether rapid genetic changes are caused by rapid rates of reproduction.

Part b

A student claims that the guppies living in the stream without predators have become a new species.

Which piece of evidence would support the student's claim?

A Guppies in the two streams are genetically different from each other.

B Guppies in the two streams cannot produce offspring with each other.

C Guppies in one stream have reproduced more rapidly than guppies in the other stream.

D Guppies in one stream are eaten by predators more often than guppies in the other stream.

Part b is aligned to the SEP and DCI. Students evaluate whether evidence supports a claim by using their content knowledge of how a new species could emerge.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: B

Distractor Rationales

Part a

A While true, this does not explain why a species that reproduces quickly was chosen.

B KEY: For 135 genes to change in one year, there must have been several generations of guppies in one year.

C While significant genetic change in a population does take several generations, not all genetic drift takes millions of years.

D Environmental factors influence natural selection and therefore evolutionary processes, but so does reproduction, which is the mechanism by which mutations are passed on.

Part b

A Genetic variation among individuals of the same species is common.

B KEY: The inability to produce offspring is evidence that organisms belong to different species.

C Different rates of reproduction could be caused by differences in environmental factors.

D This difference could be because one stream has predators and one doesn't, not because one population has become a new species.

Item 29: Standalone Item

Next Generation Science Standards Description

PE: HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

SEP: Constructing Explanations and Designing Solutions: Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

DCI: ESS1.A: The Universe and Its Stars: The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

CCC: Energy and Matter: Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems

Item Type: Open-ended

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-High

Number of Points: 4

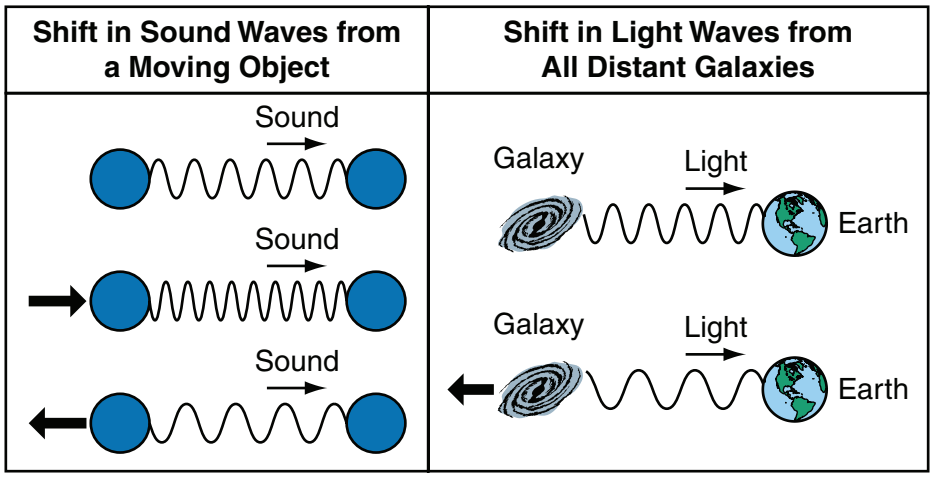
Item on next page

This item brings students into the story line by asking them to use astronomical evidence of light spectra and the motion of distant galaxies to explain changes in the universe that support the big bang theory. The item aligns to the SEP by asking students to use evidence to construct an explanation of changes in the universe. The item aligns to the DCI because students must use knowledge of how observations of redshifted light from distant galaxies and the cosmic microwave background radiation support the big bang theory. The item aligns to the CCC because students must use the understanding that energy is not destroyed as the universe expands.

A student learns about the big bang theory, which describes the early universe as very hot and very small. He also learns that scientists who study light coming to Earth from distant galaxies observe that the wavelengths of light are shifted because of the movement of the galaxies.

The diagram shows observed shifts in the wavelengths of sound waves and light waves. The arrows in the diagram show the direction of motion.

Shift in Waves



The stimulus for this item begins by presenting the phenomenon that the early universe was very different from the universe today. The hook is that a student is learning about the big bang theory. The phenomenon and hook are grade-level appropriate because many students are interested in the universe and they are likely to read about observations and the big bang theory in the news.

This question has two parts. Be sure to answer both parts of the question.

29. **a.** Use evidence from the diagram to describe one way the universe is changing. Be sure to explain how the evidence supports the change.

Scientists also observe cosmic microwave background radiation. This radiation shows that the average temperature of the universe today is very cold.

b. Describe how this radiation is another piece of evidence that supports the change in the universe described in part (a).

Part a is aligned to the SEP and DCI. Students use evidence from the diagram and their content knowledge that observations of redshifted light from distant galaxies support the big bang theory to explain how the observations can be used as evidence to describe how the universe is changing.

Part b is aligned to the SEP, DCI, and CCC. Students explain how the observed radiation is evidence that supports the description of how the universe is changing by using their content knowledge of how observations of the cosmic microwave background radiation support the big bang theory and the understanding that energy is not destroyed as the universe expands.

Scoring Rubric

Score	Description
4	The response demonstrates thorough use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response uses evidence from the diagram to describe one way the universe is changing and explains how the evidence supports the change. The response also describes how the cosmic microwave background radiation is another piece of evidence that supports the change described in part (a). The response • clearly applies science and engineering practices to provide an explanation or solution; • provides a coherent and accurate explanation or solution based on disciplinary core ideas; • reflects thorough understanding of complex ideas and crosscutting concepts; and • effectively applies and demonstrates complete understanding of the three dimensions.
3	The response demonstrates sufficient use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack some detail or information, or the response may contain minor errors in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
2	The response demonstrates limited use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems. The response may lack multiple details or information, or the response may contain major error(s) in applying and demonstrating understanding of science and engineering practices, disciplinary core ideas, and crosscutting concepts.
1	The response demonstrates minimal use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
0	The response is inaccurate, is irrelevant, or contains no evidence of use of the three dimensions to make sense of scientific phenomena and/or to design solutions to problems.
Blank	No response

The scoring rubric specifies how a 4-point response uses the dimensions of the PE and provides detail about how different levels of response meet the requirements of specific tasks in the item. All open-ended standalone items are 4-point items.

Scoring Notes

a. The universe is expanding/getting larger/full of objects that are getting farther and farther apart. The diagram shows that (all distant) galaxies are moving away from Earth. This is supported by the diagram, which shows that (all distant) galaxies are moving away from Earth/the light from all distant galaxies is shifted to longer wavelengths.

b. The universe was very hot and the radiation shows that now the universe is very cold. The universe getting bigger explains this because the same amount of energy is spread over more space.

The scoring notes provide information expected for a full credit/4-point response. They are written using the type of language most likely to be used by students.

Items 30–33: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Asking Questions and Defining Problems: Ask questions that arise from examining models or a theory to clarify relationships.

DCI: LS1.A: Structure and Function: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins.

DCI: LS3.A: Inheritance of Traits: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

PE: HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Engaging in Argument From Evidence: Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.

DCI: LS3.B: Variation of Traits:

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Cluster Overview: Cytochrome C

Item	Item Type	Alignment
30	Multiple Choice	HS-LS3-1: DCI, CCC
31	Multiple Choice	HS-LS3-2: SEP, DCI
32	Multiple Choice—Multiple Choice	HS-LS3-2: SEP, DCI, CCC
33	Multiple Choice—Multiple Choice	HS-LS3-1: SEP, DCI, CCC

Stimulus and Items on next pages

The cluster consists of a phenomenon that allows overall item alignment across two PEs. While not every individual item in the cluster is three-dimensional, all items are at least two-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

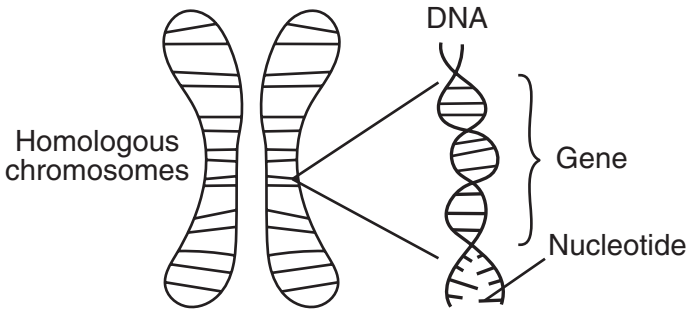
Read the information. Then answer the questions that follow.

Cytochrome C

For millions of years, many living organisms have used oxygen during cellular respiration. Some students learn that all these organisms produce a protein called cytochrome c that is used during aerobic cellular respiration. The students wonder how much the cytochrome c protein has changed during those millions of years.

To understand how generations of organisms can produce the same protein, one student draws a diagram to show relationships among the chromosomes, DNA, and genes.

Chromosomes, DNA, and Genes Model



As a result of research, the students learn that the cytochrome c protein in all organisms contains 104 amino acids. They also learn that scientists have compared the sequence of the 104 amino acids in the cytochrome c protein of different species. The number of differences between organisms in five species is shown in the table.

Number of Amino Acid Differences

	Horse	Donkey	Moth	Yeast	Wheat
Horse	—	1	29	45	46
Donkey		—	28	46	45
Moth			—	48	45
Yeast				—	47
Wheat					—

The stimulus for this item begins by presenting the phenomenon that generations of different organisms have been producing the same protein for millions of years. The hook is that students learn that all organisms that use oxygen during cellular respiration have one specific protein. The phenomenon and hook are grade-level appropriate because many students are interested in similarities and differences between species.

Item 30: Cluster Item

Next Generation Science Standards Description

PE: HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

DCI: LS3.A: Inheritance of Traits: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Low | DCI-Med | CCC-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to evaluate evidence about the role of DNA in coding the instructions for inherited traits. The item aligns to the DCI because students must use knowledge of how DNA contains instructions that code for proteins. The item aligns to the CCC because students must use evidence to support a claim that amino acid differences are caused by DNA differences.

30. One of the students claims that the amino acid differences in the table are evidence that differences in inherited traits are the result of differences in inherited DNA.

Which evidence would support the student's claim?

A Species with more amino acid differences have more genes on each DNA molecule.

B Species with more amino acid differences have different numbers of DNA molecules.

C Species with fewer amino acid differences have DNA molecules with fewer differences.

D Species with fewer amino acid differences have DNA molecules that are almost the same length.

This item is aligned to the DCI and CCC. Students use their content knowledge of how DNA contains instructions that code for proteins as evidence that supports a claim that amino acid differences are caused by DNA differences.

Scoring Key

Correct Response: C

Distractor Rationales

A More amino acid differences are caused by more genetic differences, not more genes.

B The number of amino acid differences is not directly related to the number of different chromosomes.

C KEY: Since amino acid differences are the result of genetic differences, amino acids that are more similar are the result of DNA molecules with more similar genes.

D The length of the DNA molecules is not directly related to the number of genes or to the number of genetic differences.

Item 31: Cluster Item

Next Generation Science Standards Description

PE: HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Engaging in Argument From Evidence: Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.

DCI: LS3.B: Variation of Traits: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to use evidence to defend a claim that inheritable genetic variations in yeast can result from viable errors during replication. The item aligns to the SEP by asking students to use evidence to defend a claim. The item aligns to the DCI because students must use the knowledge that genetic variation can occur because of errors in DNA replication.

31. Yeast is the only species in the table that can reproduce asexually. One student claims that there is no genetic variation when yeast reproduces asexually. Another student claims that asexual reproduction can result in genetic variation.

Which statement supports the second student's claim by describing how genetic variation can occur during asexual reproduction?

A Both daughter cells could receive a mutation.

B Chromosomes could cross over during meiosis.

C Only some of the genes could be passed to the offspring.

D An error could be made when a DNA molecule is replicated.

This item is aligned to the SEP and DCI. Students support a claim with evidence by using their content knowledge that genetic variation can occur because of errors in DNA replication.

Scoring Key

Correct Response: D

Distractor Rationales

A During asexual reproduction, both daughter cells receive identical genetic information.

B Crossing over causes genetic variation during sexual, not asexual, reproduction.

C All genes are passed on during asexual reproduction so this does not explain how genetic variation would occur.

D KEY: When a replication error occurs, the mutation can be copied during asexual reproduction and passed to offspring.

Item 32: Cluster Item

Next Generation Science Standards Description

PE: HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Engaging in Argument From Evidence: Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.

DCI: LS3.B: Variation of Traits: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to use evidence to make and defend a claim that inheritable genetic variations can result from mutations. The item aligns to the SEP by asking students to make a claim based on evidence. The item aligns to the DCI because students must use knowledge of how mutations occur and that mutations can be inherited. The item aligns to the CCC because students must use evidence to make a claim about how changes in amino acids and proteins are caused by changes in DNA.

This question has two parts. Be sure to answer both parts of the question.

32. Part a

Which claim is supported by information in the table?

A Over time, different mutations occurred in different species.

B Over time, different species developed genes with different functions.

C Over time, different species evolved different numbers of amino acids.

D Over time, different amino acids caused species to produce different proteins.

Part a is aligned to the SEP, DCI, and CCC. Students make a claim based on evidence by using their content knowledge of how mutations occur and that mutations can be inherited and their understanding of how changes in proteins are caused by changes in DNA.

Part b

How does information in the table support the claim in Part (a)?

A None of the species have the same amino acid sequences.

B All of the species produce the amino acids in cytochrome c.

C Horses and donkeys have the fewest number of amino acid differences.

D Donkeys and moths have the same number of amino acid differences with wheat.

Part b is aligned to the SEP, DCI, and CCC. Students describe how evidence supports the claim by using their content knowledge of how mutations occur and that mutations can be inherited and evidence that changes in DNA cause changes in amino acid differences.

Scoring Key

Part a
Correct Response: A

Part b
Correct Response: A

Distractor Rationales

Part a

- **A** **KEY: Mutations could have caused the genetic differences that result in the numbers of amino acid differences in the table.**
- B The differences in the table are differences in the same protein which is encoded by the same gene.
- C There is no information that any of the species do not have 104 amino acids in the protein.
- D The table shows only amino acid differences in the cytochrome c protein.

Part b

- **A** **KEY: Different numbers of mutations would have produced different numbers of genetic differences which could have caused different numbers of amino acid differences.**
- B While all the species have the amino acids needed to make cytochrome c, this does not support a claim about why there are amino acid differences among species.
- C While horses and donkeys have the fewest differences, this does not support any claim about how amino acid differences occur over time.
- D This information does not support a claim about how the passage of time results in different numbers of amino acid differences.

Item 33: Cluster Item

Next Generation Science Standards Description

PE: HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

SEP: Asking Questions and Defining Problems: Ask questions that arise from examining models or a theory to clarify relationships.

DCI: LS1.A: Structure and Function: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. DCI:

DCI: LS3.A: Inheritance of Traits: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

CCC: Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med | CCC-Low

Number of Points: 2

Item on next page

This item brings students into the story line by having them ask questions to clarify the role of DNA in coding the instructions for proteins. The item aligns to the SEP by asking students to ask questions about the relationship between the information in DNA and production of the cytochrome c protein. The item aligns to the LS1.A DCI because students must use knowledge that all cells contain genetic information in the form of DNA molecules. The item aligns to the LS3.A DCI because students must use knowledge of how DNA contains instructions that code for proteins. The item aligns to the CCC because students must use evidence to make a claim that differences in DNA cause differences in the protein that is produced.

This question has two parts. Be sure to answer both parts of the question.

33. The students want to use the diagram to understand how organisms produce cytochrome c.

Part a

Which question should the students ask?

A Are organisms always producing proteins?

B Do different organisms produce different proteins?

C How do organisms use energy to produce proteins?

D What information do organisms use to produce proteins?

Part a is aligned to the SEP, DCI, and CCC. Students ask a question about how organisms produce cytochrome c by using their content knowledge that cells contain DNA molecules with instructions that code for proteins and how the given model contains evidence of how organisms produce proteins.

Part b

Which statement describes the relationship between DNA and cytochrome c?

A The order of genes in a DNA molecule determines the structure of the protein.

B The order of nucleotides in a DNA molecule determines the structure of the protein.

C The number of genes in a DNA molecule determines which proteins will be produced.

D The number of nucleotides in a DNA molecule determines which proteins will be produced.

Part b is aligned to the DCI and CCC. Students use their content knowledge of how DNA molecules contain instructions that code for proteins as evidence to make a claim that differences in DNA cause differences in the protein that is produced.

Scoring Key

Part a
Correct Response: D

Part b
Correct Response: B

Distractor Rationales

Part a

A This would allow students to understand when, but not how, organisms produce proteins like cytochrome c.

B This would allow students to understand which organisms produce proteins like cytochrome c but not how the proteins are produced.

C Knowing how organisms use energy to produce proteins may be helpful, but focusing only on energy will not help students understand how organisms produce cytochrome c.

D KEY: Knowing what information is needed to produce proteins will help students understand what information is needed to produce cytochrome c.

Part b

A The order of nucleotides in a gene, not the location of the gene on a chromosome, determines the structure of the protein.

B KEY: The sequence of nucleotides determines the structure of a gene, the amino acid sequence coded for by the gene, and the structure of the protein produced.

C The number of genes relates to the number, not structure, of proteins.

D The order, not number, of nucleotides determines the amino acid sequence and the structure of the protein.

Items 34–37: Cluster: Stimulus and Items

Next Generation Science Standards Description

PE: HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

SEP: Constructing Explanations and Designing Solutions: Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience: Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species

DCI: LS4.D: Biodiversity and Humans:

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

PE: HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

SEP: Constructing Explanations and Designing Solutions: Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Influence of Science, Engineering, and Technology on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Cluster Overview: Trouble in the Water

Item	Item Type	Alignment
34	Multiple Choice	HS-ETS1-3: SEP, DCI, CCC
35	Multiple Choice	HS-LS2-7: SEP, DCI
36	Order—Inline Choice	HS-LS2-7: SEP, DCI
36 PBT	Multiple Choice—Multiple Choice	HS-LS2-7: SEP, DCI
37	Drag and Drop—Multi-select	HS-ETS1-3: SEP, DCI, CCC
37 PBT	Multi-select—Multi-select	HS-ETS1-3: SEP, DCI, CCC

The cluster consists of a phenomenon that allows overall item alignment across two PEs. While not every individual item in the cluster is three-dimensional, all items are at least two-dimensional, and collectively the whole cluster has strong alignment to all three dimensions of each PE.

Stimulus and Items on next pages

Read the information. Then answer the questions that follow.

Trouble in the Water

Students in a small city observe that many fish in the city's river are dying. The students do some research and learn that groundwater can become contaminated when human activities release chemicals and waste products into the environment. Contaminated groundwater can flow into rivers and harm living organisms that use the contaminated water.

Concerned about losing biodiversity in their river, the students alert state wildlife biologists. The wildlife biologists do a survey to determine the river's current biodiversity in order to compare that to historical biodiversity. The table shows nine species that had historically been found at six locations along the river. An "X" indicates that the biologists found the species at that location during their survey.

The stimulus for this item begins by presenting the phenomenon that human activities contaminate groundwater and affect river organisms. The hook is that students observe fish dying in a river close to their city. The phenomenon and hook are grade-level appropriate because many students are familiar with environmental damage where they live.

Aquatic Species Present along the River

Species	Location					
	1	2	3	4	5	6
Bluegill	X	X	X			
Common Carp	X	X	X	X	X	X
Flathead Catfish	X	X	X		X	X
Freshwater Drum	X		X			X
Golden Orb Mussel	X					
Longnose Gar	X	X	X		X	X
Pugnow Minnow	X	X	X		X	
Rainbow Trout	X	X	X		X	
Smallmouth Bass	X					

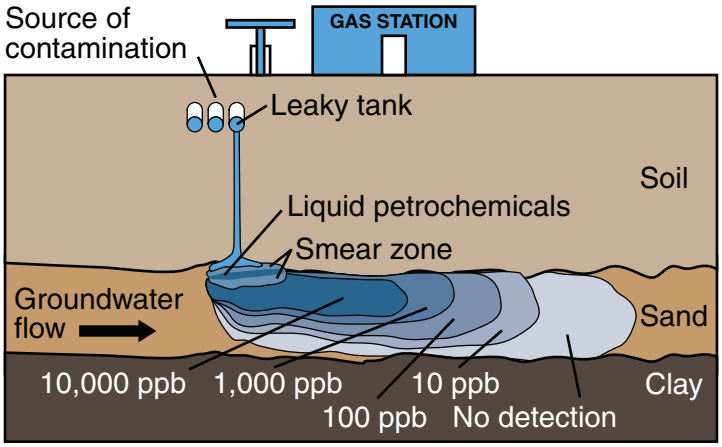
Officials in the students' city hire environmental engineers who find an underground gasoline tank at an abandoned gas station near the river. The engineers know that gasoline contains petrochemicals that can harm living organisms. The table shows the health effects of different levels of petrochemicals. The levels are given in parts per billion (ppb).

Contamination Guide

Level (ppb)	Health Impact of Petrochemicals
0–99	No known effects on health
100–2,000	Small effects on health
2,000–4,000	If short term, effects on health are negligible; If long term, can cause death
4,000 or greater	Deadly to living organisms

The engineers determine that the gas tank is leaking and liquid from the tank has reached the shores of the river. They estimate that 3,000 cubic meters of soil is contaminated. The diagram shows the estimated amount of petrochemical contamination in parts per billion (ppb) near the leaky tank.

Contamination Plume



City officials want a solution that will:

- clean the soil around the gas tank as quickly as possible
- not harm organisms that live in and around the river
- cost less than $200,000

The officials research possible solutions. Information about four possible solutions is shown in the table.

Contamination Solutions

Information	Electrocoagulation (EC)	Bioremediation	Emulsified Zero Valent Iron (EZVI)
What is done	Apply electrical charge into soil	Inject mixture of nutrients, enzymes, and microbes into soil	Inject iron particles into soil directly above groundwater
What happens	Contaminants settle out of groundwater	Contaminants broken down by microbes into non-toxic compounds	Contaminants react with iron to form non-toxic compounds
Which contaminants are treated	Heavy metal ions in groundwater	Petrochemicals in soil	Chlorinated solvents in groundwater
Effect on organisms	Can electrocute microbes in soil	Adds microbes that can spread to other locations	None
Cost per application	$9,000	$120,000	$150,000
Time to remove contaminants	Hours or days	Months	Days or months

Item 34: Cluster Item

Next Generation Science Standards Description

PE: HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

SEP: Constructing Explanations and Designing Solutions: Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Influence of Science, Engineering, and Technology on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low | CCC-Low

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to evaluate solutions to the problems caused by a leaking gasoline tank based on city officials' criteria and the constraints of the real-world problem. The item aligns to the SEP by asking students to evaluate solutions to the complex real-world problem. The item aligns to the DCI because students must use knowledge of how to evaluate solutions by taking into account a range of constraints. The item aligns to the CCC because students must analyze costs and benefits of the solutions.

34. The city officials need to evaluate the solutions in order to choose one solution.

How can city officials choose the **best** solution for their city?

A Choose the solution that meets most of the city's criteria.

B Choose the solution that permanently solves the problem.

C Choose the solution that uses the most up-to-date technology.

D Choose the solution that has the largest impact on the environment.

This item is aligned to the SEP, DCI, and CCC. Students evaluate solutions that address contamination from the leaking gasoline tank by using their content knowledge of how to evaluate solutions by taking into account a range of constraints and how to include analysis of costs and benefits in the decision-making process.

Scoring Key

Correct Response: A

Distractor Rationales

A **KEY: None of the solutions meets all the criteria, but some solutions meet more than others and this is part of evaluating solutions.**

B None of the solutions permanently solves the problem, especially if the leaking tank is still in the ground.

C Whether the solution is high-tech or uses the latest tech may or may not be relevant to whether the solution meets the city's criteria.

D This is vague: the impact could be positive or negative, long-term or short-term, slow or quick.

Item 35: Cluster Item

Next Generation Science Standards Description

PE: HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

SEP: Constructing Explanations and Designing Solutions: Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Item Type: Multiple Choice

Cognitive Complexity: Stimulus-Med | SEP-Med | DCI-Med

Number of Points: 1

Item on next page

This item brings students into the story line by asking them to evaluate a solution for reducing the impact of a leaking gasoline tank on fish in the nearby river. The item aligns to the SEP by asking students to use scientific knowledge to evaluate a solution to the problem. The item aligns to the DCI because students must use knowledge of how to take constraints into account when evaluating solutions.

35. A city official reviews the data about aquatic species along the river and the contamination plume. She suggests that the solution be used at the location where most of the fish are dying.

Which statement describes a **disadvantage** of her suggestion?

A The leaking gas tank is near the river.

B The number of aquatic species varies along the river.

C Using the solution here will increase biodiversity along the river.

D Most of the contamination plume is likely to be far from this location.

This item is aligned to the SEP and DCI. Students use their content knowledge of how to take constraints into account when evaluating solutions and scientific knowledge to evaluate a proposed solution.

Scoring Key

Correct Response: D

Distractor Rationales

A This would be an advantage, not a disadvantage, if the fish are dying near the leaky tank.

B While true, this is not clearly a disadvantage unless we know that the number is smallest near the leaky tank.

C If this is true, this is an advantage, not a disadvantage.

D KEY: The plume extends far from the tank and most of the fish are dying far from the center of the plume.

Item 36: Cluster Item

Next Generation Science Standards Description

PE: HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

SEP: Constructing Explanations and Designing Solutions: Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience: Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

Item Type: Order—Inline Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to evaluate the impact of contaminated groundwater on the biodiversity of fish in the river near a leaking gasoline tank. The item aligns to the SEP by asking students to use scientific knowledge to evaluate where a solution to the problem would be most effective. The item aligns to the DCI because students must use knowledge of how environmental changes caused by human activity can disrupt an ecosystem.

This question has two parts. Be sure to answer both parts of the question.

36. The wildlife biologists' survey showed changes in biodiversity along the river near the leaking underground gasoline tank.

Part a

Based on the data from the survey, put the locations in order from highest biodiversity to lowest biodiversity.

Select each location and drag it to the correct position in the sequence.

Highest biodiversity

location 1

location 2

location 3

location 4

location 5

location 6

Lowest biodiversity

Part b

Based on data from the survey, select the location that is farthest from the leaking tank.

Location [1, 2, 3, 4, 5, 6] is farthest from the leaking tank.

Part a is aligned to the SEP and DCI. Students use their content knowledge of how environmental changes caused by human activity can disrupt an ecosystem and scientific knowledge to evaluate where a solution to the problem would be most effective.

Part b is aligned to the SEP and DCI. Students use their content knowledge of how environmental changes caused by human activity can disrupt an ecosystem and scientific knowledge to explain where a solution to the problem would be most effective.

Scoring Key

Part a

Correct Response:

Highest biodiversity
location 1
location 3
location 2
location 5
location 6
location 4
Lowest biodiversity

Part b

Correct Response:

Location [**1**, 2, 3, 4, 5, 6] is farthest from the leaking tank.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 36: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

SEP: Constructing Explanations and Designing Solutions: Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience: Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

Item Type: Multiple Choice—Multiple Choice

Cognitive Complexity: Stimulus-Low | SEP-Low | DCI-Low

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to evaluate the impact of contaminated groundwater on the biodiversity of fish in the river near a leaking gasoline tank. The item aligns to the SEP by asking students to use scientific knowledge to evaluate where a solution to the problem would be most effective. The item aligns to the DCI because students must use knowledge of how environmental changes caused by human activity can disrupt an ecosystem.

This question has two parts. Be sure to answer both parts of the question.

36. The wildlife biologists' survey showed changes in biodiversity along the river near the leaking underground gasoline tank.

Part a

Based on the data from the survey, which sequence represents the locations in order from highest biodiversity to lowest biodiversity?

A $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6$

B $1 \rightarrow 3 \rightarrow 2 \rightarrow 5 \rightarrow 6 \rightarrow 4$

C $4 \rightarrow 6 \rightarrow 5 \rightarrow 2 \rightarrow 3 \rightarrow 1$

D $6 \rightarrow 5 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

Part a is aligned to the SEP and DCI. Students use their content knowledge of how environmental changes caused by human activity can disrupt an ecosystem and scientific knowledge to evaluate where a solution to the problem would be most effective.

Part b

Based on the data from the survey, which location is farthest from the leaking tank?

A Location 1

B Location 2

C Location 3

D Location 4

E Location 5

F Location 6

Part b is aligned to the SEP and DCI. Students use their content knowledge of how environmental changes caused by human activity can disrupt an ecosystem and scientific knowledge to explain where a solution to the problem would be most effective.

Scoring Key

Part a
Correct Response: B

Part b
Correct Response: A

Distractor Rationales

Part a

A The student ordered the locations by number, not by amount of biodiversity.

B KEY: The location with the most species has the highest biodiversity and vice versa.

C The student ordered the locations thinking that more species means lower, not higher, biodiversity.

D The student ordered the locations without thinking of biodiversity.

Part b

A KEY: Location 1 has the highest biodiversity and was therefore farthest from the tank with lowest exposure to petrochemicals so that the most species survived.

B Location 2 has fewer species than Locations 1 and 3, suggesting that this location was closer to the tank than those locations.

C Location 3 has fewer species than Location 1, suggesting that this location was closer to the tank than that location because fewer species survived petrochemical exposure.

D Location 4 has the lowest biodiversity, suggesting that this location was closest to, not farthest from, the tank.

E Location 5 has fewer species than Locations 1, 2, and 3, suggesting that this location was closer to the tank than those locations.

F Location 6 has fewer species than Locations 1, 2, 3, and 5, suggesting that this location was closer to the tank than those locations.

Item 37: Cluster Item

Next Generation Science Standards Description

PE: HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

SEP: Constructing Explanations and Designing Solutions: Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Influence of Science, Engineering, and Technology on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Item Type: Drag and Drop—Multi-select

Cognitive Complexity: Stimulus-Low | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to evaluate a solution to a leaking gasoline tank based on criteria and trade-offs. The item aligns to the SEP by asking students to use scientific knowledge to evaluate the solution based on criteria and trade-off considerations. The item aligns to the DCI because students must use knowledge of how to evaluate solutions by taking into account a range of constraints. The item aligns to the CCC because students must analyze costs and benefits of the solutions.

This question has two parts. Be sure to answer both parts of the question.

37. Some city officials recommended using EZVI because the process treats contaminated water.

Part a

Complete the table to show **two** ways EZVI could meet the needs of the city.

Select the X and drag it into the correct spaces in the table. The X can be used more than once.

Evaluating EZVI

Costs less than $200,000	
Removes the gasoline tank	
Can treat soil contamination	
Cleans up gasoline contamination	
Can be completed in six months or less	

X

Part a is aligned to the SEP and DCI. Students use their content knowledge of how to evaluate solutions by taking into account a range of constraints to evaluate how well the solution meets the city's criteria.

Part b

There are disadvantages to using EZVI to clean up the water.

Which **two** statements best describe reasons to use a different solution?

A EC applies electrical charge to soil.

B Bioremediation treats petrochemicals in soil.

C EC uses microbes to remove petrochemicals.

D Bioremediation does not add chemicals to soil.

E EC causes contaminants to form non-toxic compounds.

Part b is aligned to the SEP, DCI and CCC. Students evaluate trade-offs of the solution by using their content knowledge of how to evaluate solutions by taking into account a range of constraints and analyzing the costs, or disadvantages, of the solution.

Scoring Key

Part a

Correct Response:

Evaluating EZVI

Costs less than $200,000	X
Removes the gasoline tank	
Can treat soil contamination	
Cleans up gasoline contamination	
Can be completed in six months or less	X

X

Part b

Correct Response: B, D

Distractor Rationales

Part b

A Applying electric charge to soil will not treat petrochemicals in the soil any better than what is done during EZVI.

B KEY: Petrochemicals are the contaminant in the soil, and the table states that bioremediation can treat this contaminant.

C The table states that this is true of bioremediation, not of EC.

D KEY: This is an advantage of bioremediation over EZVI because bioremediation does not add chemicals that could harm organisms living in and along the river.

E Information in the table shows this to be true of bioremediation (and EZVI), but not of EC.

WHAT FOLLOWS IS THE STIMULUS AND PBT VERSION OF THE PREVIOUS ITEM

Item 37: PBT Cluster Item

Next Generation Science Standards Description

PE: HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

SEP: Constructing Explanations and Designing Solutions: Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

DCI: ETS1.B: Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

CCC: Influence of Science, Engineering, and Technology on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Item Type: Multi-select—Multi-select

Cognitive Complexity: Stimulus-Low | SEP-Med | DCI-Med | CCC-Med

Number of Points: 2

Item on next page

This item brings students into the story line by asking them to evaluate a solution to a leaking gasoline tank based on criteria and trade-offs. The item aligns to the SEP by asking students to use scientific knowledge to evaluate the solution based on criteria and trade-off considerations. The item aligns to the DCI because students must use knowledge of how to evaluate solutions by taking into account a range of constraints. The item aligns to the CCC because students must analyze costs and benefits of the solutions.

This question has two parts. Be sure to answer both parts of the question.

37. Some city officials recommended using EZVI because the process treats contaminated water.

Part a

Which **two** ways could EZVI meet the needs of the city?

A costs less than $200,000

B removes the gasoline tank

C can treat soil contamination

D cleans up gasoline contamination

E can be completed in six months or less

Part a is aligned to the SEP and DCI. Students use their content knowledge of how to evaluate solutions by taking into account a range of constraints to evaluate how well the solution meets the city's criteria.

Part b

There are disadvantages to using EZVI to clean up the water.

Which **two** statements best describe reasons to use a different solution?

A EC applies electrical charge to soil.

B Bioremediation treats petrochemicals in soil.

C EC uses microbes to remove petrochemicals.

D Bioremediation does not add chemicals to soil.

E EC causes contaminants to form non-toxic compounds.

Part b is aligned to the SEP, DCI and CCC. Students evaluate trade-offs of the solution by using their content knowledge of how to evaluate solutions by taking into account a range of constraints and analyzing the costs, or disadvantages, of the solution.

BACK TO TOC

Scoring Key

Part a
Correct Response: A, E

Part b
Correct Response: B, D

Distractor Rationales

Part a

- **A KEY: Officials want a solution that costs less than $200,000 and EZVI costs $150,000.**
- B EZVI removes solvents in groundwater, not the gasoline tank.
- C EZVI only treats chlorinated solvents in groundwater, not contaminants in soil.
- D EZVI only treats chlorinated solvents, not petrochemicals like gasoline.
- **E KEY: The table shows that EZVI can take days or months to remove contaminants.**

Part b

- A Applying electric charge to soil will not treat petrochemicals in the soil any better than what is done during EZVI.
- **B KEY: Petrochemicals are the contaminant in the soil, and the table states that bioremediation can treat this contaminant.**
- C The table states that this is true of bioremediation, not of EC.
- **D KEY: This is an advantage of bioremediation over EZVI because bioremediation does not add chemicals that could harm organisms living in and along the river.**
- E Information in the table shows this to be true of bioremediation (and EZVI) but not of EC.