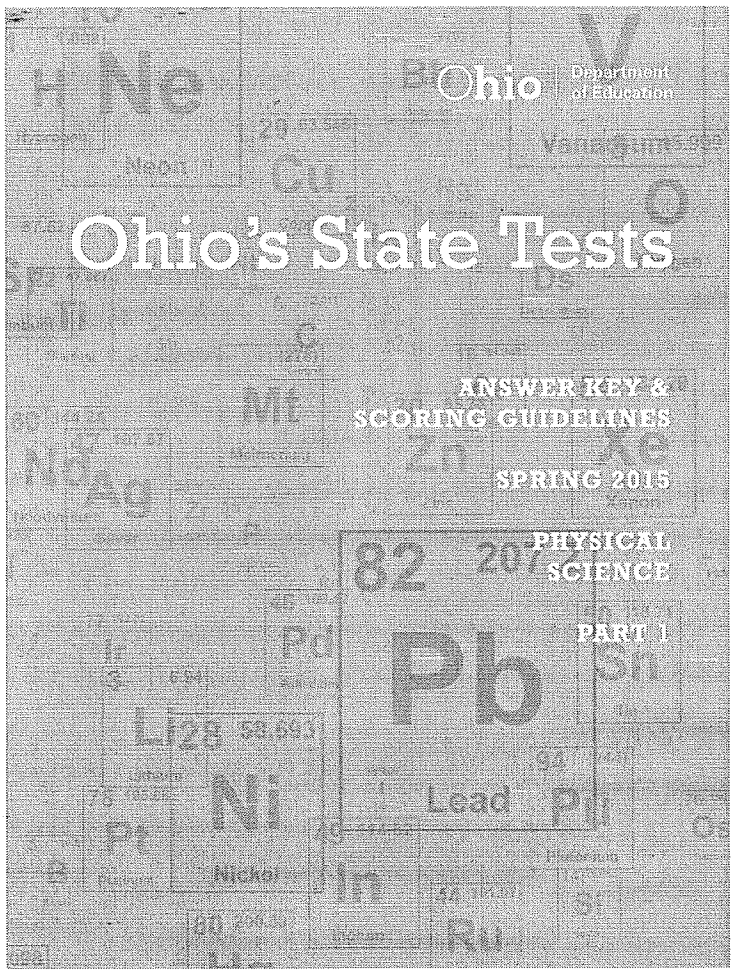

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Physical Science
PBA Practice Test
Content Summary and Answer Key

Question No.	Item Type	Topic	Subtopic	Answer Key	Points
1	Graphic Response	Study of Matter	Classification of Matter	---	2 points
2	Graphic Response	Energy and Waves	Transfer and Transformation of Energy (including work)	---	2 points
3	Short Response	Energy and Waves	Transfer and Transformation of Energy (including work)	---	2 points
4	Graphic Response	Forces and Motion	Forces	---	2 points
5	Simulation*	Forces and Motion	Dynamics	---	---
6	Graphic Response	Forces and Motion	Forces	---	2 points
7	Graphic Response	Energy and Waves	Transfer and Transformation of Energy (including work)	---	1 point
8	Graphic Response	Forces and Motion	Dynamics	---	1 point

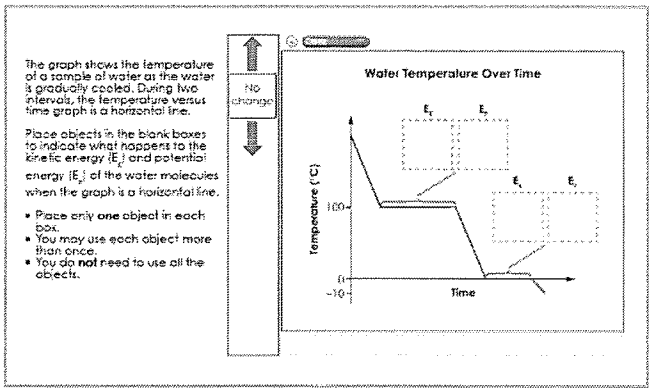
*The Simulation is numbered but not scored.

Physical Science
PBA Practice Test

Question 1

Question and Scoring Guidelines

Question 1



Points Possible: 2

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit response includes

- Down arrows in the two Potential Energy (E_P) boxes (1 point)

  AND

- "No change" labels in the two Kinetic Energy (E_K) boxes (1 point).

Alignment

Topic
Study of Matter

Subtopic
Classification of Matter

Content Elaboration
"Phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. investigations must include collecting data during heating, cooling and solid-liquid-solid phase changes. At times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. Since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles. When heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. Conversely, when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes. Phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic)."

Cognitive Demand
Interpreting and Communicating Science Concepts (C)

Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.

Explanation of the Item
This two-point graphic response item requires the student to interpret a cooling curve to determine how the kinetic and potential energy of water molecules change in two intervals of the graph. A temperature change in a substance indicates a change in kinetic energy of the particles of the substance. All other variables being constant, an increase in temperature indicates an increase in kinetic energy and a decrease in

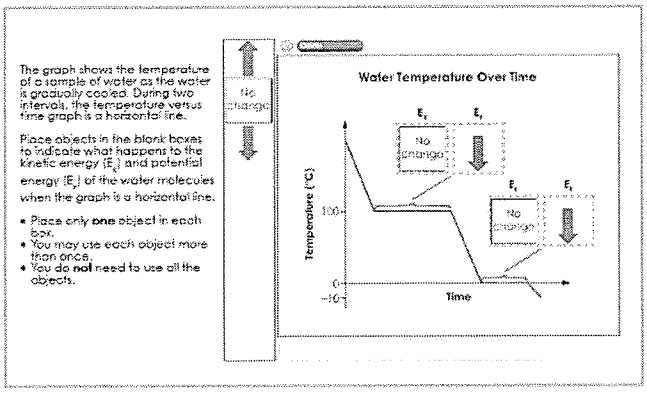
temperature indicates a decrease in kinetic energy. In the two intervals of the graph indicated, the temperature remains constant, indicating no change in kinetic energy. However, since this is a cooling graph, the total energy must be decreasing. Since the kinetic energy is remaining constant, it must be potential energy that is being decreased. In fact, these two intervals represent phase changes from gas to liquid and liquid to solid, respectively. In phase changes, the positions of the particles that make up the substance change, which changes the potential energy of the particles. In both intervals, the kinetic energy remains constant and the potential energy is decreased.

Physical Science
PBA Practice Test

Question 1

Sample Responses

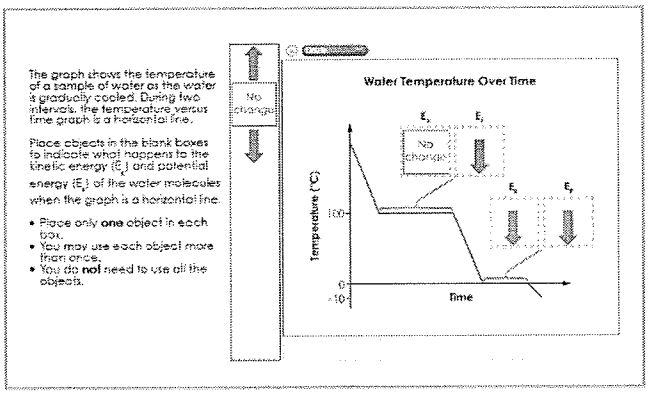
Sample Response: 2 points



Notes on Scoring

This response earns full credit (2 points) because it indicates the kinetic energy is constant in both intervals and the potential energy decreases in both intervals.

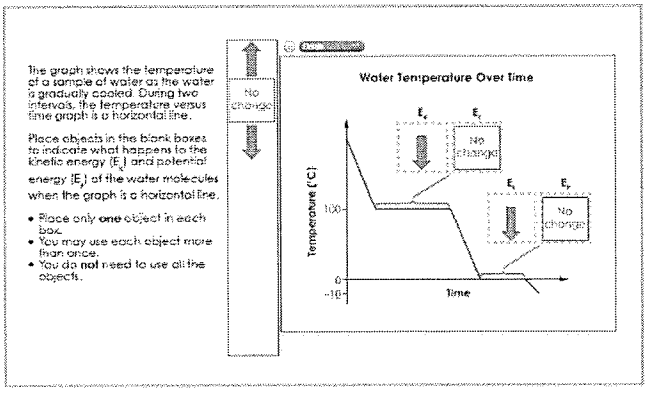
Sample Response: 1 point



Notes on Scoring

This response earns partial credit (1 point) for indicating the potential energy decreases in both intervals. While the response correctly indicates there is no change in kinetic energy in the first interval, it incorrectly indicates that the kinetic energy decreases in the second interval. Since the temperature remains constant in the second interval, the kinetic energy actually remains constant as well. The response did not correctly indicate the kinetic energy of both intervals, so only partial credit can be awarded.

Sample Response: 0 points



Notes on Scoring

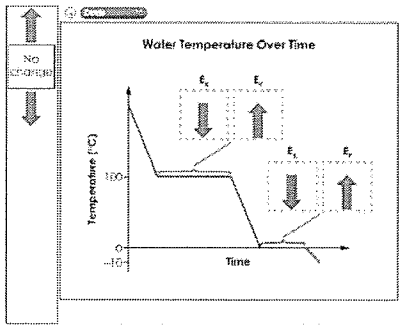
This response earns no credit (0 points) since none of the energies is correctly indicated. The responses for kinetic energy and potential energy are switched from what would be a correct response.

Sample Response: 0 points

The graph shows the temperature of a sample of water as the water is gradually cooled. During two intervals, the temperature versus time graph is a horizontal line.

Place objects in the blank boxes to indicate what happens to the kinetic energy (E_k) and potential energy (E_p) of the water molecules when the graph is a horizontal line.

- Place only **one** object in each box.
- You may use each object more than once.
- You do **not** need to use all the objects.



Notes on Scoring

This response earns no credit (0 points) since none of the energies is correctly indicated.

Physical Science PBA Practice Test

Question 2

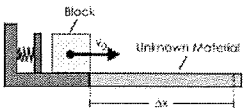
Question and Scoring Guidelines

Question 2

Transfer and Transformation of Energy

A student tests how different materials affect a sliding block. The student places a block in front of a compressed spring and then releases the spring. The block slides across an unknown material. The student measures the distance that the block travels on the unknown material before it comes to rest (Δx).

Experimental Setup



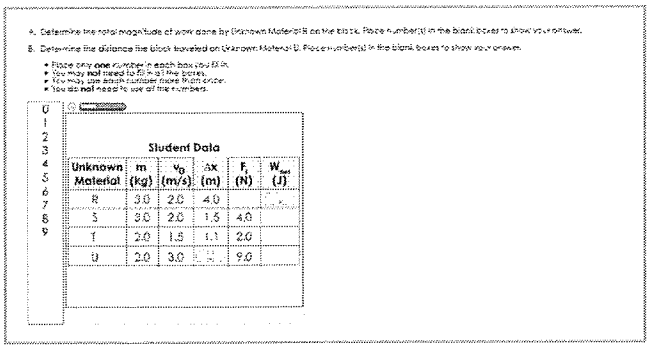
The student changes the mass of the block, but otherwise the block is the same in all trials. Some of the student's data from the first four trials are shown.

Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0		9.0	

Variable Key

m	Mass
v_0	Initial velocity
Δx	Distance traveled
F_f	Magnitude of friction force
W_{net}	Total magnitude of work done by friction on block



Points Possible: 2

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit response includes

- 6 or 6.0 in the Unknown Material R, W_{net} table cell (1 point)

  AND

- 1 or 1.0 in the Unknown Material U, delta x table cell (1 point).

Alignment

Topic
Energy and Waves

Subtopic
Transfer and Transformation of Energy (including work)

Content Elaboration
"In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, F, and displacement, Δx, are in the same or opposite directions, work, W, can be calculated from the equation $W = F\Delta x$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems."

Cognitive Demand
Interpreting and Communicating Science Concepts (C)

"Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information."

Explanation of the Item
This two-point graphic response item requires the student to use data, conservation of energy and work to determine both the work done on a block and the distance the block traveled. In Part A, the student is asked to calculate the work done on a block by Unknown Material R. Data is given for the mass (3.0 kg), initial velocity (2.0 m/s) and distance traveled by the block (4.0 m). Initially the block has kinetic energy, which is equal to $\frac{1}{2}mv^2$. As the block slides along Unknown Material R, friction does work on the block, transferring the kinetic energy into thermal energy, until the block stops and the final velocity and kinetic energy is zero. Therefore, for this particular situation, due to conservation of energy, the work done on the block by the surface is equal to the initial kinetic energy of the block or $W = \frac{1}{2}mv^2$. Substituting values into the equation gives $W = \frac{1}{2}(3.0\text{ kg})(2.0\text{ m/s})^2 = 6.0\text{ J}$.

For Part B, the student is asked to calculate the distance the block travels on Unknown Material U. Data is given for the mass of the block (2.0 kg), the initial velocity of the block (3.0 m/s) and friction force acting on the block (9.0 N). Using the same reasoning in Part A, the work done on the block is equal to the initial kinetic energy of the block or $W = \frac{1}{2}mv^2$. Work can also be calculated by using the equation $W = F\Delta x$. These equations can be set equal to each other, $\frac{1}{2}mv^2 = F\Delta x$. Solving the equation for Δx gives $\Delta x = (\frac{1}{2}mv^2)/F$. Substituting in numbers gives $\Delta x = [\frac{1}{2}(2.0\text{ kg})(3.0\text{ m/s})^2]/(9.0\text{ N}) = 1.0\text{ m}$.

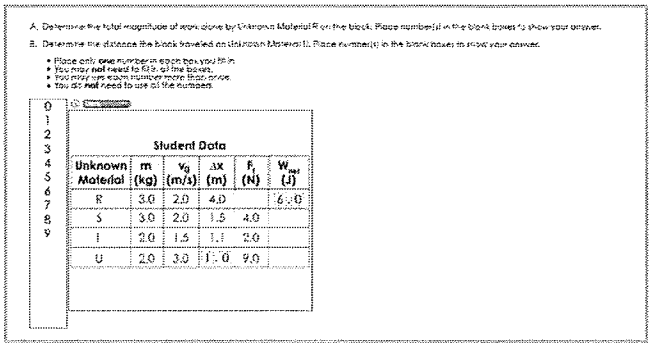
This item is worth two points: one for correctly calculating the work that Unknown Material R does on the block and one for correctly calculating the distance the block travels on Unknown Material U. Answers can be expressed to one significant figure (6 J and 1 m) or two (6.0 J and 1.0 m) to earn full credit.

Physical Science PBA Practice Test

Question 2

Sample Responses

Sample Response: 2 points



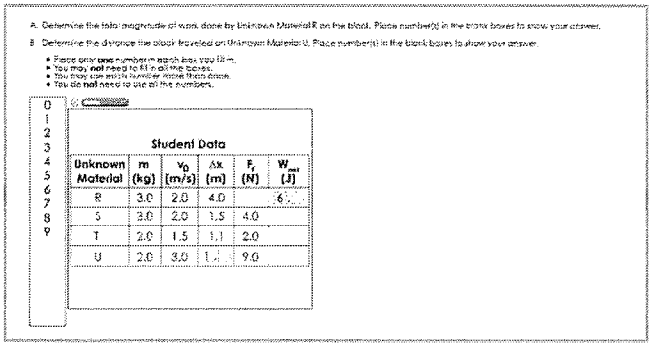
Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		6.0
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	1.0	9.0	

Notes on Scoring

This response earns full credit (2 points) because it indicates the work done on the block by Unknown Material R as "6.0" J [$W = \frac{1}{2}$ (3.0 kg) (2.0 m/s)^2 = 6.0 J] and the distance the block traveled on Unknown Material U as "1.0" m [Δx = [$\frac{1}{2}$ (2.0 kg) (3.0 m/s)^2]/ (9.0 N) = 1.0 m]. This is an example of expressing the answers to two significant figures to earn full credit.

Sample Response: 2 points



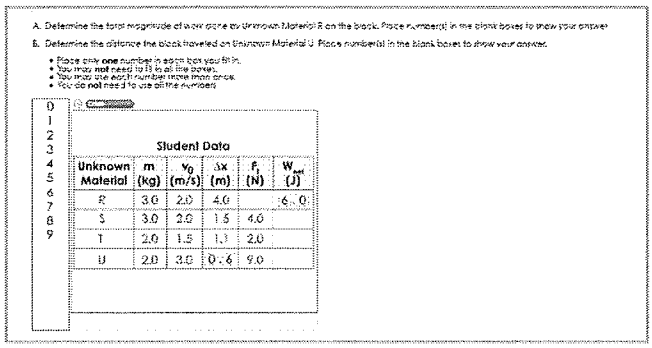
Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		6
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	1.0	9.0	

Notes on Scoring

This response earns full credit (2 points) because it indicates the work done on the block by Unknown Material R as "6" J [$W = \frac{1}{2}$ (3.0 kg) (2.0 m/s)^2 = 6.0 J] and the distance traveled by the block on Unknown Material U as "1" m [Δx = [$\frac{1}{2}$ (2.0 kg) (3.0 m/s)^2]/ (9.0 N) = 1.0 m]. This is an example of expressing the answers to one significant figure to earn full credit.

Sample Response: 1 point



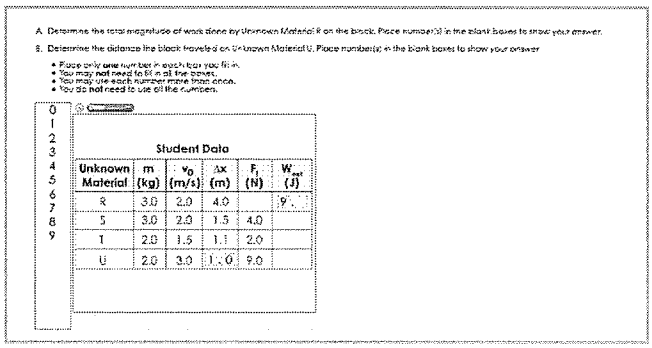
Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		6.0
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	0.6	9.0	

Notes on Scoring

This response earns partial credit (1 point) for indicating the work done on the block by Unknown Material R as "6.0" J [$W = \frac{1}{2}$ (3.0 kg) (2.0 m/s)^2 = 6.0 J]. However, "0.6" m is an incorrect response for the distance traveled by the block on Unknown Material U [Δx = [$\frac{1}{2}$ (2.0 kg) (3.0 m/s)^2]/ (9.0 N) = 1.0 m] and does not earn the second point.

Sample Response: 1 point



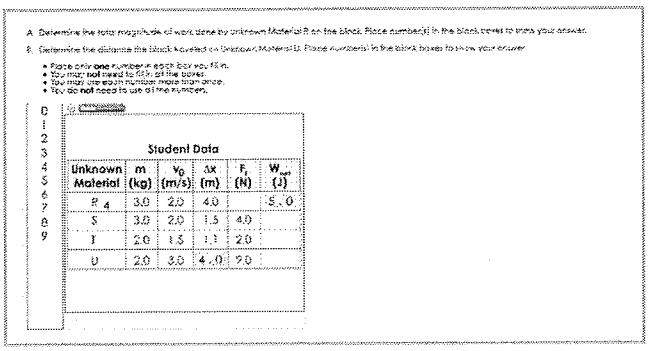
Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		9
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	1.0	9.0	

Notes on Scoring

This response earns partial credit (1 point) for indicating the distance traveled by the block on Unknown Material U is "1.0" m [Δx = [$\frac{1}{2}$ (2.0 kg) (3.0 m/s)^2]/ (9.0 N) = 1.0 m]. However, "9" J is an incorrect response for the work done on the block by Unknown Material R [$W = \frac{1}{2}$ (3.0 kg) (2.0 m/s)^2 = 6.0 J] and does not earn the second point.

Sample Response: 0 points



A. Determine the total magnitude of work done by Unknown Material R on the block. Place number(s) in the blank boxes to show your answer.

B. Determine the distance the block traveled on Unknown Material U. Place number(s) in the blank boxes to show your answer.

- Place only **one** number in each box you fill in.
- You may **not** need to fill in all of the boxes.
- You may use each number more than once.
- You do **not** need to use all the numbers.

0 1 2 3 4 5 6 7 8 9

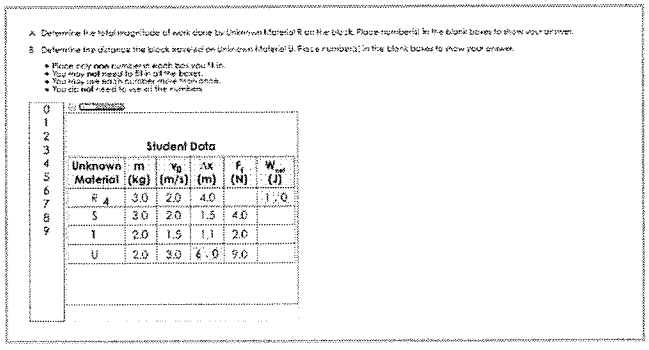
Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		5.0
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	4.0	9.0	

Notes on Scoring

This response earns no credit (0 points) because neither the work done on the block by Unknown Material R [$W = \frac{1}{2}(3.0\text{ kg})(2.0\text{ m/s})^2 = 6.0\text{ J}$] nor the distance the block traveled by the block on Unknown Material U [$\Delta x = [\frac{1}{2}(2.0\text{ kg})(3.0\text{ m/s})^2]/(9.0\text{ N}) = 1.0\text{ m}$] is correct.

Sample Response: 0 points



A. Determine the total magnitude of work done by Unknown Material R on the block. Place number(s) in the blank boxes to show your answer.

B. Determine the distance the block traveled on Unknown Material U. Place number(s) in the blank boxes to show your answer.

- Place only **one** number in each box you fill in.
- You may **not** need to fill in all of the boxes.
- You may use each number more than once.
- You do **not** need to use all the numbers.

0 1 2 3 4 5 6 7 8 9

Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		1.0
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0	6.0	9.0	

Notes on Scoring

This response earns no credit (0 points) because neither the work done on the block by Unknown Material R [$W = \frac{1}{2}(3.0\text{ kg})(2.0\text{ m/s})^2 = 6.0\text{ J}$] nor the distance traveled by the block on Unknown Material U [$\Delta x = [\frac{1}{2}(2.0\text{ kg})(3.0\text{ m/s})^2]/(9.0\text{ N}) = 1.0\text{ m}$] is correct.

Physical Science
PBA Practice Test

Question 3

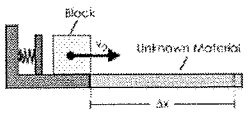
Question and Scoring Guidelines

Question 3

Transfer and Transformation of Energy

A student tests how different materials affect a sliding block. The student places a block in front of a compressed spring and then releases the spring. The block slides across an unknown material. The student measures the distance that the block travels on the unknown material before it comes to rest (Δx).

Experimental Setup



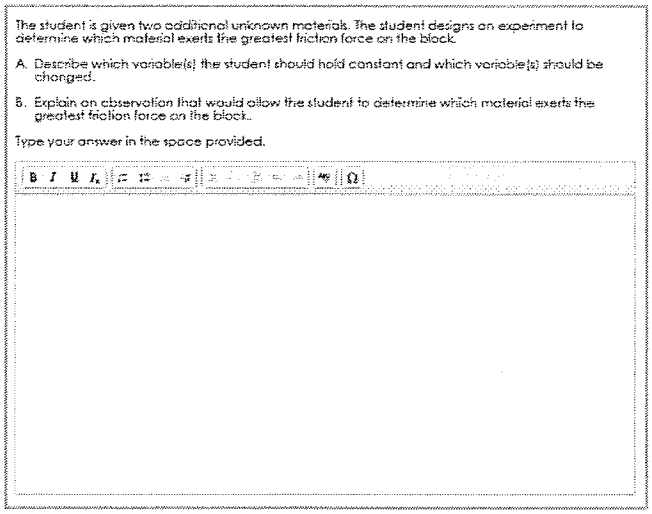
The student changes the mass of the block, but otherwise the block is the same in all trials. Some of the student's data from the first four trials are shown.

Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0		9.0	

Variable Key

m	Mass
v_0	Initial velocity
Δx	Distance traveled
F_f	Magnitude of friction force
W_{net}	Total magnitude of work done by friction on block



Points Possible: 2

See **Alignment** for more detail.

Scoring Guidelines

Score Point	Description
2 points	The response includes • a correct description of the variable(s) to hold constant and the variable(s) to change AND • a correct description of an observation that would allow the student to determine which material has the greatest friction force.
1 point	The response includes • a correct description of the variable(s) to hold constant and the variable(s) to change OR • a correct description of an observation that would allow the student to determine which material has the greatest friction force.
0 points	The response does not meet the criteria required to earn one point. The response indicates inadequate or no understanding of the task and/or the idea or concept needed to answer the item. It may only repeat information given in the test item. The response may provide an incorrect solution/response and the provided supportive information may be irrelevant to the item, or possibly, no other information is shown. The student may have written on a different topic or written, "I don't know."

Alignment

Topic
Energy and Waves

Subtopic
Transfer and Transformation of Energy (including work)

Content Elaboration
"In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy.

Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, **F**, and displacement, Δx, are in the same or opposite directions, work, **W**, can be calculated from the equation $W = F\Delta x$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems."

Cognitive Demand
Demonstrating Science Knowledge (D)

Requires students to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards)

Note: Procedural knowledge (knowing how) is included in Recalling/Identifying Accurate Science.

Explanation of the Item
This two-point short response item requires the student to design an experiment to determine which floor material would have the greatest friction and to describe the experimental evidence that would be used to make this determination. Since the student is asked to determine which floor material would have the greatest friction, the student needs to change the type of floor material while holding other variables constant. Important variables to keep constant would be the mass of the block and the initial velocity of the block (which could be controlled by using the same spring and compressing it by the same amount to launch the block).

Students would then measure the distance the block traveled on the different unknown surfaces before stopping. Initially, the blocks have kinetic energy, which is equal to $\frac{1}{2} mv^2$. Since all blocks will have the same mass and initial velocity, they will have the same initial kinetic energy. As the block slides along Unknown Material R, friction does work on the block, transferring the kinetic energy into thermal energy, until the block stops and the final velocity and kinetic energy is zero. Since all blocks have the same initial kinetic energy and final kinetic energy, the same amount of energy is transferred and transformed and the same amount of work is done on the blocks. Since $W = F\Delta x$ or $W = F = W/(\Delta x)$, and the same amount of work is done on all

blocks, the surface that allows the block to travel the shortest distance will be the surface with the most friction.

Students could also choose to measure the amount of time the block takes to come to a stop. Substituting $a = \{v_f - v_i\} / t$ into $F = ma$ gives $F = [m \{v_f - v_i\}] / t$. Since the mass, the initial velocity and the final velocity of the block are constant for all surfaces, the force is inversely proportional to the amount of time it takes for the block to stop. This means that as the force increases, the amount of time it takes the block to stop decreases. The surface that stops the block in the least amount of time will exert the greatest force on the block.

Describing the variables to change and hold constant earns one point. Explaining how to determine which material exerts the greatest friction force earns the second point. This can be accomplished by either relating the distance the block moves before stopping or the time it takes the block to stop, to the greatest friction force.

Physical Science
PBA Practice Test

Question 3

Sample Responses

Sample Response: 2 points

The student is given two additional unknown materials. The student designs an experiment to determine which material exerts the greatest friction force on the block.

A. Describe which variable(s) the student should hold constant and which variable(s) should be changed.

B. Explain an observation that would allow the student to determine which material exerts the greatest friction force on the block.

Type your answer in the space provided.

He should keep the speeds the same, and the weight of the block. He should only change the material. He will know which material has the greatest friction force by observing which one went a shorter distance.

Notes on Scoring

This response earns full credit (2 points). One point is earned for "He should keep the speeds the same, and the weight of the block. He should only change the material." The response is not penalized for the use of the term "weight" instead of "mass."

The response earns the second point for "He will know which material has the greatest friction force by observing which one went a shorter distance." The response links a specific observation "a shorter distance" to the conclusion "the greatest friction force."

Sample Response: 2 points

The student is given two additional unknown materials. The student designs an experiment to determine which material exerts the greatest friction force on the block.

A. Describe which variable(s) the student should hold constant and which variable(s) should be changed.

B. Explain an observation that would allow the student to determine which material exerts the greatest friction force on the block.

Type your answer in the space provided.

There are two variables that the student should hold constant in his/her experiment. These variables are the force the spring puts on the block and the block itself, which should be changed as little as possible if at all. An observation that would allow the student to determine which material exerts the greatest friction force on the block would definitely be how far each block traveled, or the distance. This is because the less friction force there is the longer it will take for the material to stop the block, so the shortest distance should be the material that had the greatest friction force.

Notes on Scoring

This response earns full credit (2 points). One point is earned for "the student should hold constant . . . the force the spring puts on the block and the block itself" and "to determine which material exerts the greatest friction force on the block." "The force the spring puts on the block" was given credit for a property of the spring that must be kept constant. "The block itself" was enough to imply the mass is kept constant. The statement "to determine which material exerts the greatest friction force on the block" implies that the material must be changed, even though the student did not explicitly state this.

The response earns the second point for ". . . the shortest distance should be the material that had the greatest friction force." The response clearly links a specific observation, "the shortest distance," to the conclusion "the greatest friction force."

Sample Response: 1 point

The student is given two additional unknown materials. The student designs an experiment to determine which material exerts the greatest friction force on the block.

A. Describe which variable(s) the student should hold constant and which variable(s) should be changed.

B. Explain an observation that would allow the student to determine which material exerts the greatest friction force on the block.

Type your answer in the space provided.

The variable that should stay the same is the mass. The only variable that should change is the unkown material. The best way to observe which material exerts the greatest friction force on the block is by seeing which material stops the block faster.

Notes on Scoring

This response earns partial credit (1 point). The response does not earn credit for identifying the variables that are held constant and changed. While the response does correctly indicate "The variable that should stay the same is mass." and "The only variable that should change is the unkown material.", it does not state anything about keeping the initial velocity the same or the properties of the spring that could be kept constant to give the same initial velocity for each trial.

The response earns the second point for "the best way to observe which material exerts the greatest friction force on the block is by seeing which material stops the block faster." The response clearly links a specific observation "which material stops the block fastest" with a conclusion "the greatest friction force."

Sample Response: 1 point

The student is given two additional unknown materials. The student designs an experiment to determine which material exerts the greatest friction force on the block.

A. Describe which variable(s) the student should hold constant and which variable(s) should be changed.

B. Explain an observation that would allow the student to determine which material exerts the greatest friction force on the block.

Type your answer in the space provided.

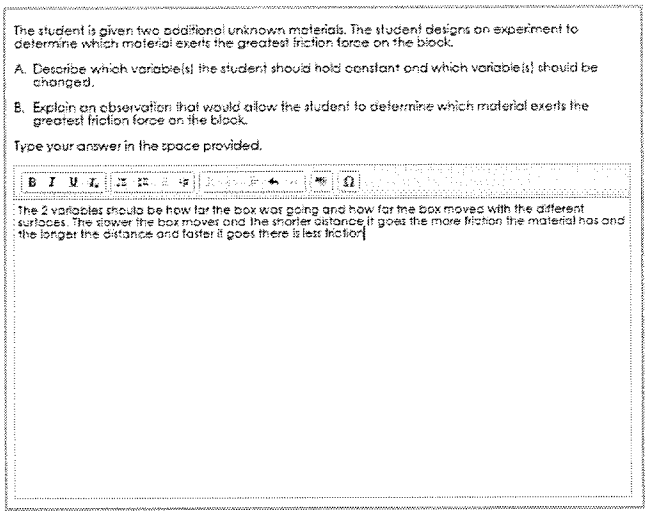
The mass of the block and the spring should remain constant and the unknown material should change so as the difference between materials can be seen. A student can determine which one has the greatest friction force by seeing wich one takes the shortest time to stop.

Notes on Scoring

This response earns partial credit (1 point). The response does not earn credit for identifying the variables that are held constant and changed. The response does correctly indicate "The mass of the block . . . should remain constant" and "the unknown material should change." However, "the spring should remain constant" was not specific enough for the student to earn credit. The variables that should be held constant for the spring (i.e., compression, force) to produce a constant velocity are not identified.

The response earns the second point for "A student can determine wich one has the greatest friction force by seeing wich one takes the shortest time to stop." The response clearly links a specific observation "the shortest time to stop" with a conclusion "the greatest friction force."

Sample Response: 1 point

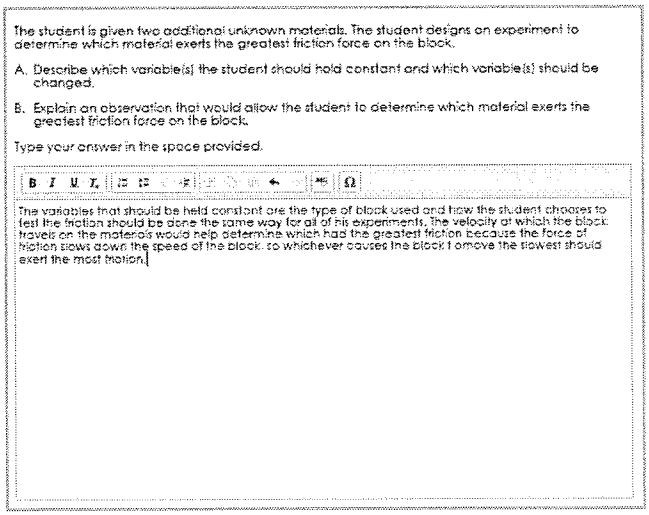


Notes on Scoring

This response earns partial credit (1 point). The response does not earn credit for identifying the variables that are held constant and changed. "The 2 variables should be how far the box was going and how far the box moved with the different surfaces" does not indicate the important independent and controlled variables. Nor does it indicate whether the variables identified should be kept constant and what should be changed.

The response earns the second point for ". . .the shorter distance it goes the more friction the material has . . .". The response clearly links an observation "the shorter distance" with a conclusion "the more friction the material has." The statement "The slower the box moves" is not correct because both boxes slow from the initial speed to zero, giving the same range of speeds for each trial. The response is too vague to earn credit for identifying that the material in which the block takes less time to stop exerts the greatest friction force on the block. However, since a correct observation is given, this statement is ignored and is not counted against the response.

Sample Response: 0 points



Notes on Scoring

This response earns no credit (0 points). The discussion of the variables is not complete enough or clear enough to determine which variables should be kept constant and what should be changed. The statement "The velocity at which the block travels . . ." is not clear enough or complete enough to earn credit. All materials would cause the block to slow and eventually stop, giving the same range of velocities for each trial. The response is too vague to earn credit for identifying that the material in which the block takes less time to stop exerts the greatest friction force on the block.

Sample Response: 0 points

The student is given two additional unknown materials. The student designs an experiment to determine which material exerts the greatest friction force on the block.

A. Describe which variable(s) the student should hold constant and which variable(s) should be changed.

B. Explain an observation that would allow the student to determine which material exerts the greatest friction force on the block.

Type your answer in the space provided.

The student should hold constant the **mass of the block** and the **material the block is made of.** The student should change the **material the block will slide on.** The student could observe **how slow or how quick** the block slides down the material.

Notes on Scoring

This response earns no credit (0 points). The response correctly indicates "The student should hold constant the **mass of the block**. . ." and "The student should change the **material the block will slide on**." However, the response does not indicate the initial velocity should be kept constant, nor does it indicate the properties of the spring that could be kept constant to produce a constant initial velocity.

The statement "The student could observe **how slow or how quick** the block slides down the material. . ." is not clear enough or complete enough to earn credit. All materials would cause the block to slow and eventually stop, giving the same range of speeds for each trial. The response is too vague to earn credit for identifying that the material in which the block takes less time to stop exerts the greatest friction force on the block. In addition, "**how slow or how quick**" is not tied to a conclusion. The response does not indicate if a greater force would be indicated by sliding slowly or sliding quickly.

Physical Science
PBA Practice Test

Question 4

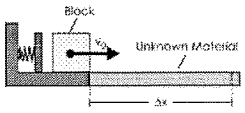
Question and Scoring Guidelines

Question 4

Transfer and Transformation of Energy

A student tests how different materials affect a sliding block. The student places a block in front of a compressed spring and then releases the spring. The block slides across an unknown material. The student measures the distance that the block travels on the unknown material before it comes to rest (Δx).

Experimental Setup



The student changes the mass of the block, but otherwise the block is the same in all trials. Some of the student's data from the first four trials are shown.

Student Data

Unknown Material	m (kg)	v_0 (m/s)	Δx (m)	F_f (N)	W_{net} (J)
R	3.0	2.0	4.0		
S	3.0	2.0	1.5	4.0	
T	2.0	1.5	1.1	2.0	
U	2.0	3.0		9.0	

Variable Key

m	Mass
v_0	Initial velocity
Δx	Distance traveled
F_f	Magnitude of friction force
W_{net}	Total magnitude of work done by friction on block

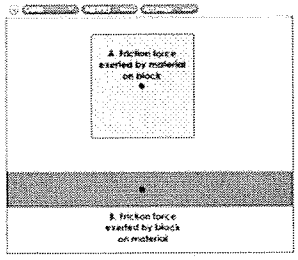
The diagram shows the block and object to the right across an unknown material.

A. Use the Add Arrow button to draw a single arrow that represents the friction force exerted by the material on the block.

B. Use the Add Arrow button to draw a single arrow that represents the friction force exerted by the block on the material.

Ensure that the length of each arrow represents the relative strength of the force.

- Start each arrow from a black dot.



Points Possible: 2

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit (2 point) response includes

- An arrow starting or ending at the center of the block pointed to the left AND an arrow starting or ending at the center of the material pointed to the right

  AND

- The arrow starting at the center of the block has the same length and is pointed in the opposite direction as the arrow starting at the center of the material.

For this item, a partial-credit (1 point) response includes

- An arrow starting or ending at the center of the block pointed to the left AND an arrow starting or ending at the center of the material pointed to the right

  OR

- The arrow starting at the center of the block has the same length and is pointed in the opposite direction as the arrow starting at the center of the material

  OR

- Two arrows that each start on one of the three snap points in the vertical middle of the box and each connect vertically with a snap point that is in the vertical center of the material AND the two arrows are going in opposite directions.

Alignment

Topic
Forces and Motion

Subtopic
Forces

Content Elaboration
"A force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. Interacting force pairs are often confused with balanced forces. Interacting force pairs can never cancel each other out because they always act on different objects. Naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. Objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign, therefore, the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down, so the book pulls Earth up with an equal force. The focus of the content is to develop a conceptual understanding of the laws of motion to explain and predict changes in motion, not to name or recite a memorized definition."

Cognitive Demand

Interpreting and Communicating Science Concepts (C)

Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.

Explanation of the Item

This two-point graphic response item requires the student to draw force diagrams to represent that interactive friction forces have the same magnitude but act in opposite directions. A force is an interaction between two objects.

Forces always occur in pairs acting on both of the interacting objects. This situation examines the friction force between a block and the material upon which it slides. Friction acts in a direction opposite to the relative motion of the object. Since the block is moving to the right with respect to the material, the friction force on the block will act to the left on the block. Since the material is moving to the left with respect to the block, the friction force will act to the right on the material. This is consistent with the law of motion that states that interacting force pairs act in opposite directions to one another. In addition, the law states these interacting forces will be equal to one another. This will be indicated by the arrows being the same length.

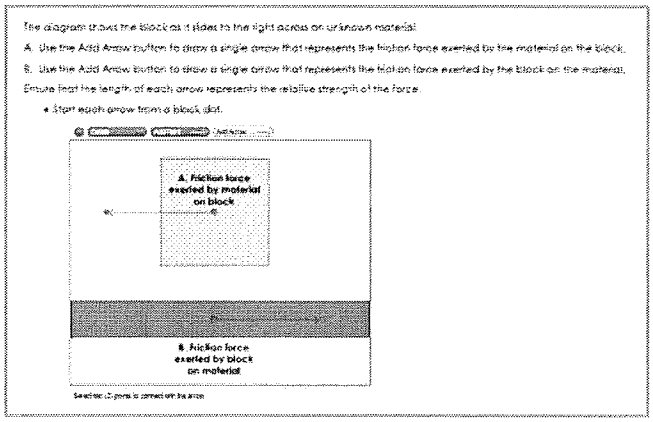
Responses earn one point for showing the friction force acting to the left on the block and to the right on the material. A second point is earned if the arrows are equal in length.

Physical Science PBA Practice Test

Question 4

Sample Responses

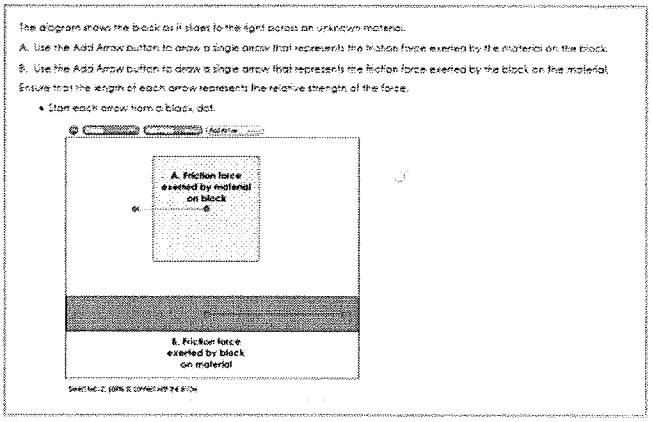
Sample Response: 2 points



Notes on Scoring

This response earns full credit (2 points). One point is earned for drawing an arrow to the left on the block and an arrow to the right on the material. The second point is earned for drawing the arrows so they are equal in length.

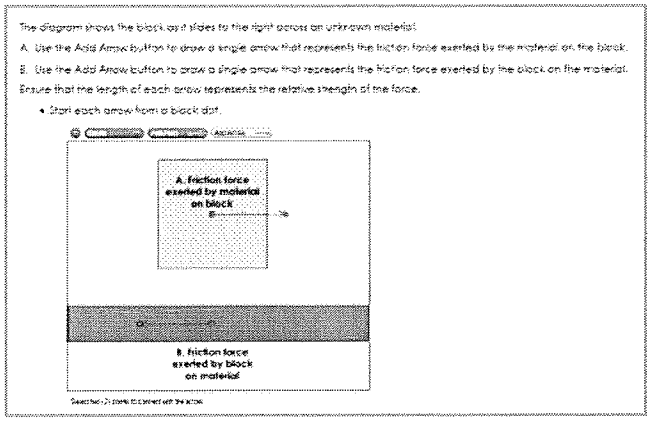
Sample Response: 1 point



Notes on Scoring

This response earns partial credit (1 point). One point is earned for drawing an arrow to the left on the block and an arrow to the right on the material. The second point is not earned since the arrows are drawn to different lengths.

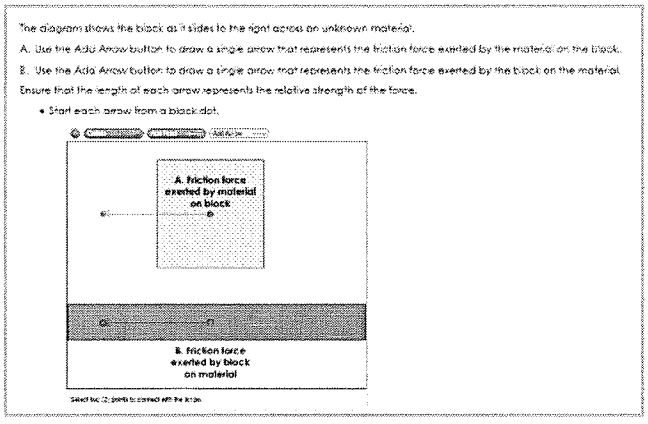
Sample Response: 1 point



Notes on Scoring

This response earns partial credit (1 point). One point is earned for drawing the two arrows of equal length in opposite directions. However, the direction of the arrow on the block points to the right, not to the left, and the direction of the arrow on the material points to the left, not to the right. Since the directions are not correct, two points cannot be earned.

Sample Response: 0 points

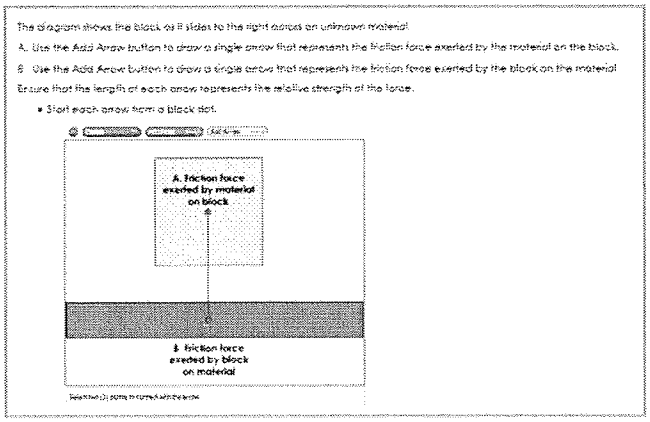


Notes on Scoring

This response earns no credit (0 points). While the arrow on the block points to the left, the arrow on the material also points to the left, so the response does not earn credit for indicating the correct direction of the forces.

While the two arrows are equal in length, they are not opposite in direction, so the response cannot earn credit for showing arrows that are equal in length and opposite in direction.

Sample Response: 0 points



Notes on Scoring

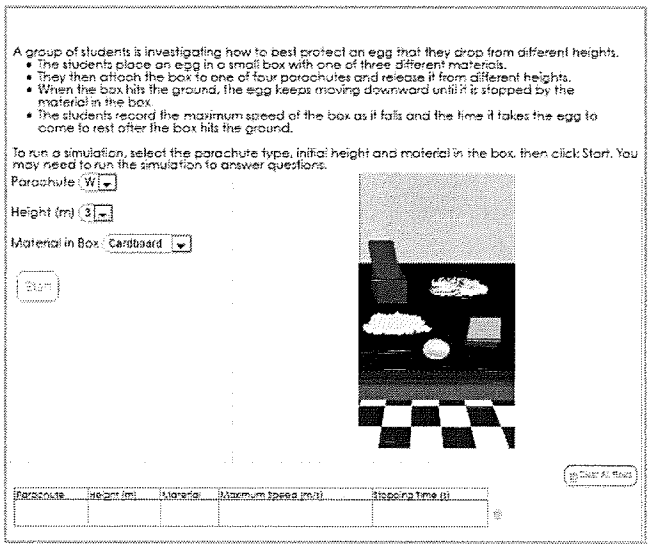
This response earns no credit (0 points). Only one vertical arrow is drawn. Since friction forces act parallel to the surfaces, the response cannot earn credit for indicating the correct direction. In addition, the response does not show two equal length arrows pointing in opposite directions, so the second point is not earned.

Physical Science
PBA Practice Test

Question 5

Simulation for Questions 6 – 8

Question 5 (Simulation for Questions 6 – 8)

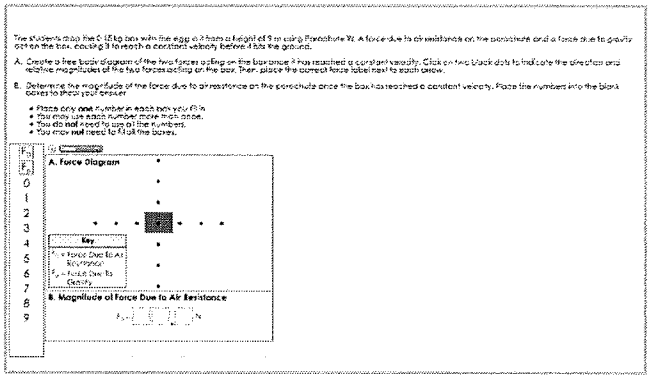


Physical Science
PBA Practice Test

Question 6

Question and Scoring Guidelines

Question 6



Points Possible: 2

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit response includes

- An upward arrow selected and labeled "F_D" that is the same length as the downward selected arrow that is labeled "F_g" (1 point)

  AND

- 1.5 or equivalent in "F_D" (1 point).

Alignment

Topic
Forces and Motion

Subtopic
Forces

Content Elaboration
"Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams that were introduced in middle school."

"The gravitational force (weight) of an object is proportional to its mass, m. Weight, F_g, can be calculated from the equation $F_g = mg$, where g is the gravitational field strength of an object, which is equal to 9.8 N/kg (m/s²) on the surface of Earth."

Cognitive Demand
Interpreting and Communicating Science Concepts (C)

Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.

Explanation of the Item
This two-point graphic response item is associated with a simulation. The student is not required to run the simulation to answer this question. However, the situation referenced in the simulation is the context for the question. This item requires the student to represent the forces acting on a falling box that have reached a constant velocity in a force diagram and to calculate the force due to air resistance acting on a parachute attached to the box.

Since the velocity is constant, it can be deduced that no net force acts on the box. This means the force of air resistance must be equal in magnitude and opposite in direction to the force of gravity. The force of gravity is from the attraction of the box toward earth and points downward. The force of air resistance points in a direction opposite to motion. Since the box is falling downward, air resistance points upward. Arrows of equal length represent that the force of gravity is equal to the force of air resistance.

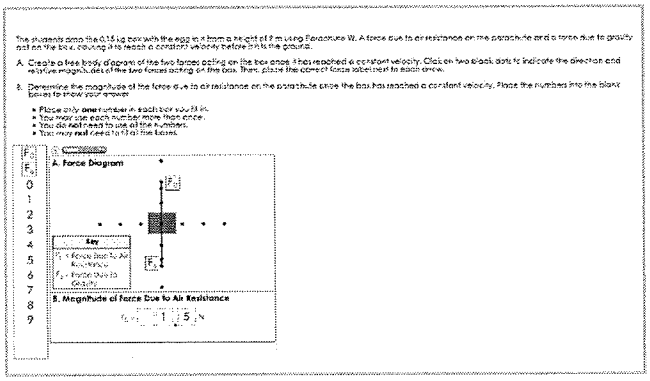
The force of air resistance is equal to the force of gravity because the box is moving at a constant speed. The force of gravity can be calculated using the equation $F_g = mg$, where m is the mass and **g** is the gravitational field strength (10 N/kg on Earth's surface). Substituting values into the equation gives $F_g = (0.15\ kg)(10\ N/kg) = 1.5\ N$. Since $F_g = F_D$, the force due to air resistance must also be 1.5 N.

Physical Science
PBA Practice Test

Question 6

Sample Responses

Sample Response: 2 points

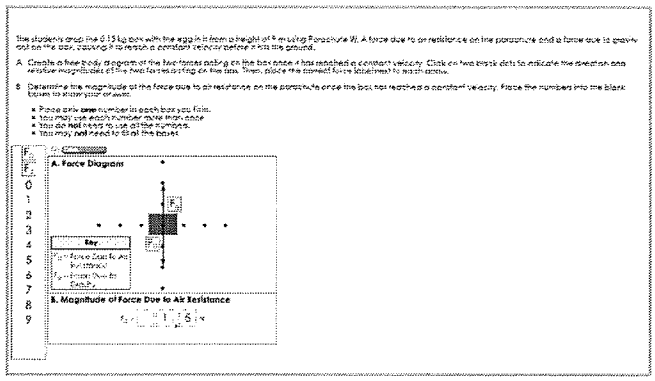


Notes on Scoring

This response earns full credit (2 points). The first point is earned by having two arrows, one pointing upward and one pointing downward, that are equal in length. The arrow pointing upward is correctly labelled "F_D" and the arrow pointing downward is correctly labelled "F_g".

The second point is earned for correctly indicating the force due to air resistance has a value of 1.5 N [$F_D = F_g = (0.15\ kg)(10\ N/kg) = 1.5\ N$].

Sample Response: 1 point

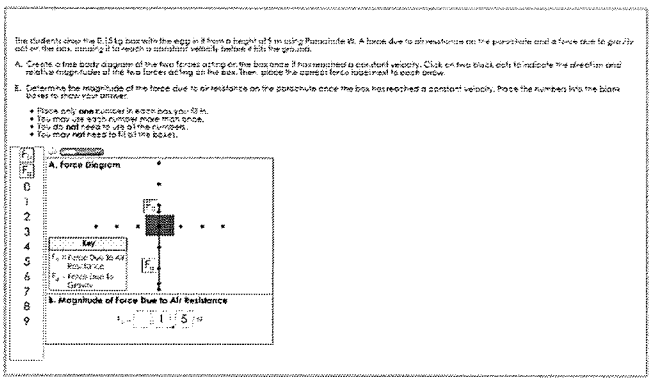


Notes on Scoring

This response earns partial credit (1 point). This response does not earn credit for the graphic. It is correct in that two equal length arrows are indicated: one pointing upward and one pointing downward. However, the arrows are not labelled correctly. The arrow pointing upward should be labelled "F_D" and the arrow pointing downward should be labelled "F_g".

This response does earn one point for correctly indicating the force due to air resistance has a value of 1.5 N [$F_D = F_g = (0.15\text{ kg})(10\text{ N/kg}) = 1.5\text{ N}$].

Sample Response: 1 point

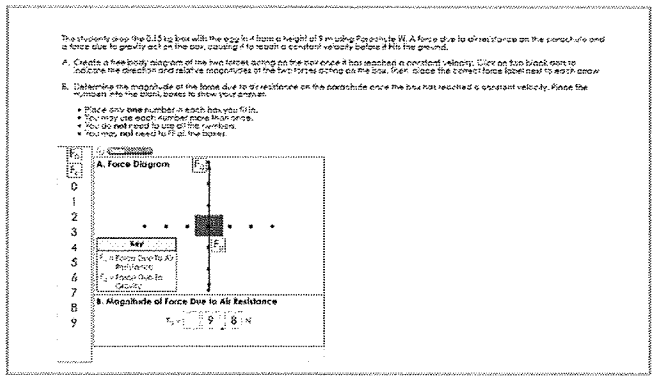


Notes on Scoring

This response earns partial credit (1 point). This response does not earn credit for the graphic. It correctly indicates that the force due to gravity acts downward and the force due to air resistance acts upward. However, the arrows are shown to be different lengths, when the forces must be equal since the box falls at constant velocity.

This response does earn one point for correctly indicating the force due to air resistance has a value of 1.5 N [$F_D = F_g = (0.15\text{ kg})(10\text{ N/kg}) = 1.5\text{ N}$].

Sample Response: 1 point

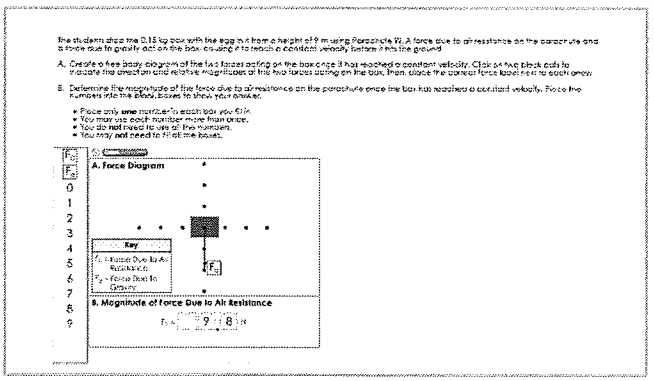


Notes on Scoring

This response earns partial credit (1 point). The graphic for this response earns one point. The response shows two arrows, one pointing upward and one pointing downward, that are equal in length. The arrow pointing upward is correctly labelled "F_D" and the arrow pointing downward is correctly labelled "F_g".

The force due to air resistance has a value of 1.5 N [$F_D = F_g = (0.15\text{ kg})(10\text{ N/kg}) = 1.5\text{ N}$]. This response incorrectly indicates the force due to air resistance as 9.8 N, so it can only earn partial credit.

Sample Response: 0 points



Notes on Scoring

This response earns no credit (0 points). While the graphic correctly identifies that the force due to gravity is downward, there is no arrow drawn for the force due to air resistance, so the graphic cannot earn credit.

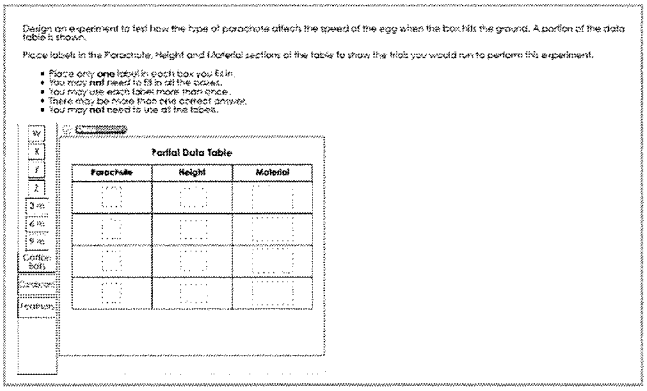
The force due to air resistance has a value of 1.5 N [$F_D = F_g = (0.15\text{ kg})(10\text{ N/kg}) = 1.5\text{ N}$]. This response incorrectly indicates the force due to air resistance as 9.8 N.

Physical Science
PBA Practice Test

Question 7

Question and Scoring Guidelines

Question 7



Points Possible: 1

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit response includes

- The same height in all four "Height" boxes and nothing else

  AND

- The same material in all four "Material" boxes and nothing else

  AND

- A different parachute in each of the four "Parachute" boxes and nothing else (1 point).

Alignment

Topic
Energy and Waves

Subtopic
Transfer and Transformation of Energy (including work)

Content Elaboration
In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, **F**, and displacement, Δx, are in the same or opposite directions, work, **W**, can be calculated from the equation $W = F\Delta x$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems. When energy is transferred from one system to another, some of the energy is transformed to thermal energy. Since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. Therefore, even though the total amount of energy remains constant, less energy is available for doing useful work.

Cognitive Demand
Demonstrating Science Knowledge (D)

Requires students to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards)

Note: Procedural knowledge (knowing how) is included in Recalling/Identifying Accurate Science.

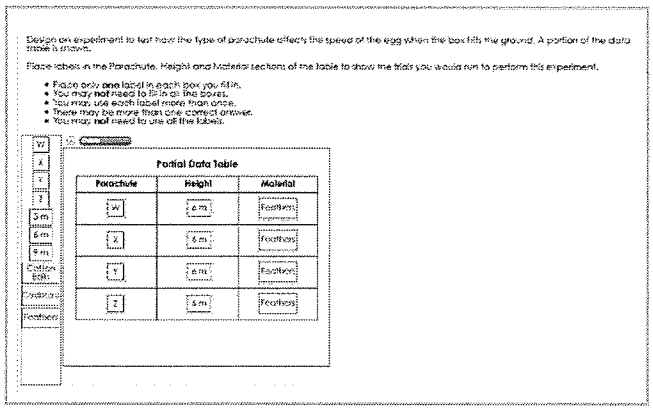
Explanation of the Item
This one-point graphic response item is associated with a simulation. The student is not required to run the simulation to answer this question. However, the situation referenced in the simulation is the context for the question. The item requires the student to design an experiment to determine how the parachute used affects the motion of a falling object. In a controlled experiment, all variables are kept constant except the one being tested. Since the experiment is looking for results based on the type of parachute that is used, this is the variable that should be changed. There are four parachutes and four trials, so a different parachute should be used in each trial. The height and the material are variables that should be kept constant. While it does not matter which values are initially chosen for height and material, the values should be consistent for each trial.

Physical Science
PBA Practice Test

Question 7

Sample Responses

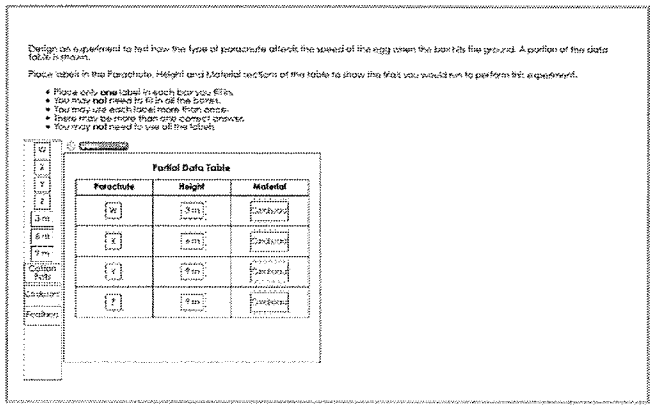
Sample Response: 1 point



Notes on Scoring

This response earns one point because the height is kept constant at 6 m for each trial, feathers are used consistently in all trials and a different parachute is used for each trial.

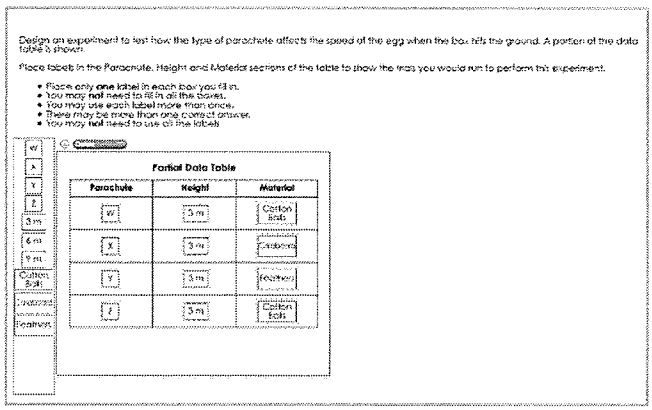
Sample Response: 0 points



Notes on Scoring

This response earns no credit (0 points). It is correct in that a different parachute is used for each trial and the same material is consistently used. However, different heights are used and are not kept constant.

Sample Response: 0 points



Notes on Scoring

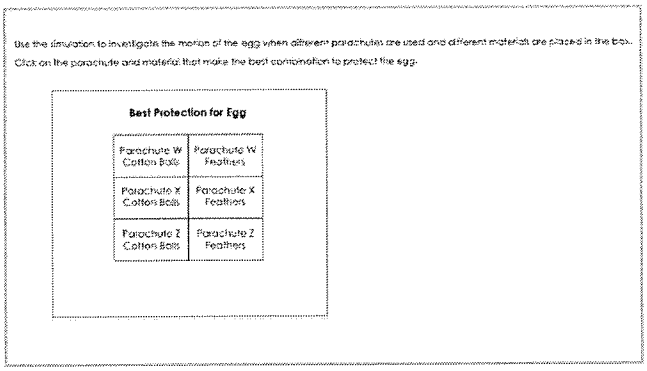
This response earns no credit (0 points). It is correct in that a different parachute is used for each trial and the same height is consistently used. However, different materials are used and are not kept constant.

Physical Science
PBA Practice Test

Question 8

Question and Scoring Guidelines

Question 8



Points Possible: 1

See **Alignment** for more detail.

Scoring Guidelines

For this item, a full-credit response includes

- "Parachute W Feathers" selected (1 point).

Alignment

Topic
Forces and Motion

Subtopic
Dynamics

Content Elaboration
"An object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced net force acts on it. The rate at which an object changes its speed or direction (acceleration) is proportional to the vector sum of the applied forces (net force, F_{net}) and inversely proportional to the mass ($a = F_{net}/m$). When the vector sum of the forces (net force) acting on an object is zero, the object does not accelerate. For an object that is moving, this means the object will remain moving without changing its speed or direction. For an object that is not moving, the object will continue to remain stationary. These laws will be applied to systems consisting of a single object upon which multiple forces act. Vector addition will be limited to one dimension (positive and negative). While both horizontal and vertical forces can be acting on an object simultaneously, one of the dimensions must have a net force of zero.

A force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. Interacting force pairs are often confused with balanced forces. Interacting force pairs can never cancel each other out because they always act on different objects. Naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. Objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign, therefore, the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down, so the book pulls Earth up with an equal force. The focus of the content is to develop a conceptual understanding of the laws of motion to explain and predict changes in motion, not to name or recite a memorized definition. In the physics syllabus, all laws will be applied to systems of many objects."

Cognitive Demand
Designing Technological/ Engineering Solutions Using Science Concepts (T)

Requires students to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or

critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives and/or integrate and synthesize scientific information.

Explanation of the Item
This one-point graphic response item is associated with a simulation. To answer this question, the student must use the simulation to perform experiments, gather data and make decisions based upon the data collected. This item requires the student to perform an investigation to gather information to determine the best combination of material in the box and parachute type to protect the dropped egg from breaking upon impact.

The danger to the egg is the force of impact. Factors that decrease this force will best protect the egg. Net force is directly proportional to acceleration, which is the rate at which velocity changes. If the acceleration is decreased, then the net force acting on the egg is also decreased. Factors that can indicate the relative magnitude of acceleration, a, are the change in velocity, Δv, and the stopping time, t, as shown in the equation $a = \Delta v/t$. The data table indicates the stopping time for each trial as well as the maximum speed. Since the box comes to a stop in all trials, the greater the maximum speed, the greater the change in velocity. Acceleration and net force are decreased with a lower change in velocity and a longer time.

One way to approach this engineering problem is to test all four parachutes under the same conditions of height and material. When this is done, it is observed that Parachute W has the lowest maximum velocity, the longest stopping time and the lowest maximum speed. Therefore Parachute W protects the egg the best because it is associated with the lowest acceleration and net force.

Now that the most protective parachute has been determined, one can now test for the most protective material. For this test, it is important to keep all factors constant except the type of material. Once all three materials are tested with the same parachute and from the same height, the data show that feathers stop the box in the greatest amount of time. This gives the lowest acceleration and net force and protects the egg the best.

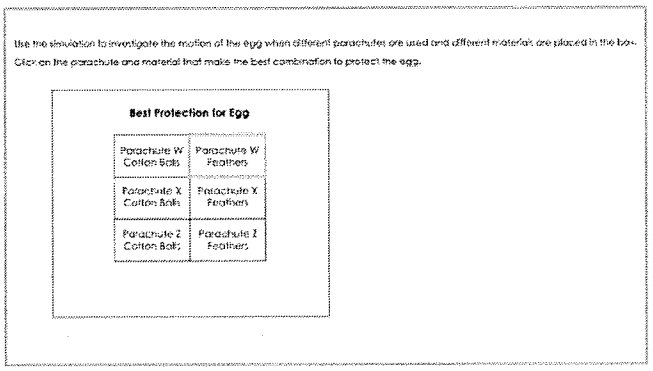
A correct response identifies the combination of Parachute W and feathers will protect the egg the best.

Physical Science
PBA Practice Test

Question 8

Sample Responses

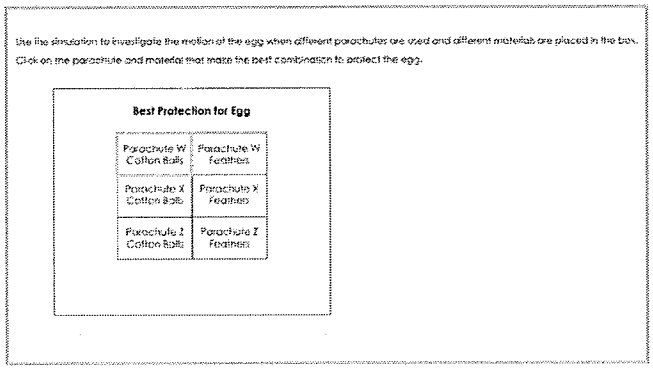
Sample Response: 1 point



Notes on Scoring

This response earns full credit (1 point). The response correctly indicates that "Parachute W" and "Feathers" is the best combination to protect the eggs and thus earns full credit.

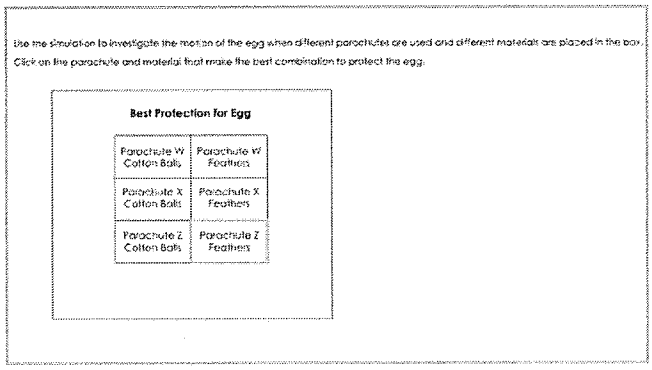
Sample Response: 0 points



Notes on Scoring

This response earns no credit (0 points). The response incorrectly indicates that "Parachute W" and "Cotton Balls" is the best combination to protect the eggs and does not earn credit. The combination of "Parachute W" and "Feathers" provides the lowest maximum velocity and the longest stopping time, offering the egg the best protection.

Sample Response: 0 points



Notes on Scoring

This response earns no credit (0 points). The response incorrectly indicates that "Parachute Z" and "Feathers" is the best combination to protect the eggs and does not earn credit. The combination of "Parachute W" and "Feathers" provides the lowest maximum velocity and the longest stopping time, offering the egg the best protection.