ASPECt
Assessing Students' Progress on the Energy Concept

Bouncing Balls: AP16-6

High School - Energy Transfer by Forces

TASK OVERVIEW

Students are introduced to two athletes who want to determine the relative amounts of energy transferred to the ground and the air as a ball bounces. First, they construct, or identify, a graph that represents the relationship between the speed of the ball and the amount of kinetic energy the ball has. Then they analyze a table of data on the speed of the ball before and after it bounces, and they identify what aspects of the data are important for figuring out the amount of energy transferred. Students are also asked to identify an equation that could be used to calculate the amount of energy transferred to the surroundings when the ball bounces. Lastly, students are presented with several claims about the relative amounts of energy transferred to the air and ground and asked to decide which claim the data supports and to provide reasoning that uses appropriate scientific principles to justify why the data supports the claim.

TARGETED DCIs, SEPs, AND CCCs

Disciplinary core ideas

- PS3.A-M.1: Motion energy is properly called kinetic energy, it is proportional to the mass of the moving object and grows with the square of its speed.

- PS3.A-M.2: A system of objects may also contain stored (potential) energy, depending on their relative positions.
- PS3.C-M.1: When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.
- PS3.B-H.1: 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.
- PS3.B-H.3: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

Science & engineering practices

- SEP4-H.1: 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.
- SEP7-H.4: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Crosscutting concepts

- CC5-H.3: Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Related Performance Expectations

- 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 energies in gravitational, magnetic, or electrical fields.]

TASK PERFORMANCE EXPECTATION

Analyze and interpret data to determine the relative amounts of energy transferred to the air and the ground when a ball bounces. *Compare and evaluate competing claims* by citing data that supports the chosen claim and use reasoning to link the evidence and ideas about energy transfer and energy conservation.

LINK TO ONLINE VERSION

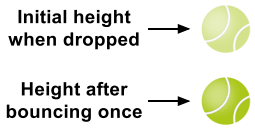
https://assess.bscs.org/i/test/677

REFERENCE

This task is based on the following reference: Stoeckel, M. (2018). Where does the energy go?: Using evidence-based reasoning to connect energy and motion. *The Science Teacher, 85*(1), 19-25.

Task

Two athletes are practicing tennis. They notice that each time they drop a tennis ball it doesn't bounce back to the height from where it was dropped.



The athletes know that the reason why the ball does not reach the initial height is because energy is transferred from the ball to somewhere else. They think that the energy is transferred in two ways: (1) from the ball to the air as the ball falls and (2) from the ball to the ground as the ball hits the ground. One athlete claims that more energy is transferred to the air than to the ground. The other athlete disagrees and claims that more energy is transferred to ground than to the air.

The athletes decide to collect data to see if they can determine whose claim is correct. They drop the ball and let it bounce until it stops bouncing. They take three videos of the ball bouncing and use computer software to analyze the speed of the ball at different times. They measure the speed of the ball before and after the first and second bounce. They make sure to measure the ball at the same height above the ground. Their data are summarized in the table below.

Trial	Column 1:  Speed right before 1st bounce (meters/sec)	Column 2:  Speed right after 1st bounce (meters/sec)	Column 3:  Speed right before 2nd bounce (meters/sec)	Column 4:  Speed right after 2nd bounce (meters/sec)
1	4.07	3.32	3.20	2.70
2	4.05	3.29	3.21	2.72
3	4.08	3.31	3.22	2.71

1. Which of the data in the table are important for understanding the amount of energy transferred from the ball to the air?

   A. The speed before the first bounce and after the first bounce (Columns 1 and 2)

   B. The speed after the first bounce and before the second bounce (Columns 2 and 3)

   C. The speed after the first bounce and after the second bounce (Columns 2 and 4)

   D. The speed before the first bounce and before the second bounce (Columns 1 and 3)

2. Which of the data in the table are important for understanding the amount of energy transferred from the ball to the ground?

   A. The speed before the first bounce and after the first bounce (Columns 1 and 2)

   B. The speed after the first bounce and before the second bounce (Columns 2 and 3)

   C. The speed after the first bounce and after the second bounce (Columns 2 and 4)

   D. The speed before the first bounce and before the second bounce (Columns 1 and 3)

3. Which athlete's claim do the data support?

   A. The data support the claim that more energy is transferred to the air than to the ground.

B. The data support the claim that more energy is transferred to the ground than to the air.

C. The data do not support either claim. The data show that an equal amount of energy is transferred to the air and the ground.

D. The data do not support either claim. The data show that no energy is transferred to the air or the ground.

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4. Use the data in the table to provide evidence to support the claim you chose.

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5. Provide reasoning that uses scientific principles about energy to justify why the evidence in the data table supports the claim you chose.

Alignment to Targeted DCIs, SEPs, and CCCs and Scoring Rubrics

QUESTION 1

Which of the data in the table are important for understanding the amount of energy transferred from the ball to the air?

A. The speed before the first bounce and after the first bounce (Columns 1 and 2)

B. The speed after the first bounce and before the second bounce (Columns 2 and 3)

C. The speed after the first bounce and after the second bounce (Columns 2 and 4)

D. The speed before the first bounce and before the second bounce (Columns 1 and 3)

LEARNING GOAL

Learning Performance

- Analyze data to identify which data are important for understanding the amount of energy transferred from the ball to the air.

Targeted DCIs, SEP, and CCC

- SEP4-H.1: 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.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Student selects the relevant data	B. The speed after the first bounce and before the second bounce (Columns 2 and 3)

QUESTION 2

Which of the data in the table are important for understanding the energy transferred from the ball to the ground?

A. The speed before the first bounce and after first bounce (Columns 1 and 2)

B. The speed after the first bounce and before the second bounce (Columns 2 and 3)

C. The speed after the first bounce and after the second bounce (Columns 2 and 4)

D. The speed before the first bounce and before the second bounce (Columns 1 and 3)

LEARNING GOAL

- Analyze data to identify which data are important for understanding the amount of energy transferred from the ball to the ground.

Targeted DCIs, SEP, and CCC

- SEP4-H.1: 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.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Student selects the relevant data	A. The speed before the first bounce and after first bounce (Columns 1 and 2)

QUESTIONS 3, 4, & 5

Which athlete's claim do the data support?

A. The data support the claim that more energy is transferred to the air than to the ground.

B. The data support the claim that more energy is transferred to the ground than to the air.

C. The data do not support either claim. The data show the claim that an equal amount of energy is transferred to the air and the ground.

D. The data do not support either claim. The data show the claim that no energy is transferred to the air or the ground.

Use the data in the table to provide evidence to support the claim you chose.

Provide reasoning that uses scientific principles about energy to justify why the evidence in the data table supports the claim you chose.

LEARNING GOAL

Learning Performance

- Select the claim that is supported by the data provided. Use data to provide evidence that supports the claim. Use reasoning to link the evidence about the changes in the speed of the ball to science principles about energy to support a claim about the relative amount of energy transferred to the air and ground during the bounce.

Targeted DCIs, SEP, and CCC

- PS3.C-M.1: When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.
- PS3.A-M.1: Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- PS3.B-H.1: 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.
- PS3.B-H.3: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- CC5-H.3: Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- SEP7-H.4: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

SCORING RUBRIC

Ideal Response

Claim in Question 3: B. The data support the claim that more energy is transferred to the ground than to the air.

Evidence for Question 4: The difference in the speeds right before the ball hit the ground and right after the ball hit the ground (4.07 – 3.32) is greater than the difference between the speeds right after the first bounce and right before the second bounce (3.32 – 3.20).

Reasoning for Question 5: Because kinetic energy is proportional to the speed of an object, the change in the ball's speed is related to a change in its kinetic energy.

Because energy cannot be created or destroyed, the decrease in the kinetic energy must be balanced by an increase in energy in the surroundings. A bigger change in speed means a bigger change in kinetic energy, and therefore a larger amount of energy transferred to the surroundings.

Elements of a Correct Response

Categories	Elements
Student selects the correct claim	B. The data support the claim that more energy is transferred to the molecules of the ground than to the molecules of the air.
Student cites evidence	• The difference in speeds during the bounce is greater than the difference in the speeds while traveling through the air.
Student either states or uses a general science idea	• The speed of an object is proportional to kinetic energy (i.e., the faster the ball falls the more energy it has). [*links energy and speed*] • The total change of energy in any system is equal to the total energy transferred into or out of the system (i.e., the change in the kinetic energy is equal to the amount of energy transferred to the objects the ball interacts with). [*links kinetic energy changes and energy transfer*]
Student states or uses a crosscutting concept	• Energy cannot be created or destroyed—only transferred from place to place (i.e., energy is conserved, or the total amount of energy doesn't change). [*conservation*]
Student uses reasoning to link evidence, science ideas, and/or crosscutting concepts	• More energy is transferred from the ball to the ground than is transferred from the ball to the air because there is a bigger change in speed before and after hitting the ground. A bigger change in speed indicates a bigger change in energy, which indicates a larger amount of energy transferred.

Sample Student Responses

Student response	Scoring description
The student selected answer choice A and wrote: "Before the first bounce its pushing the ground"	Score = 0

"The reason why is because the air is helping push the ball up."	The student did not select the correct claim.
The student selected answer choice B and wrote: "The data shows how the ball slows after the first bounce because it gets momentum stopped by the ground" "When the ball hits the ground the speed that it had gets slowed down because the ground forces it to stop."	Score = 1 The student selected the correct claim but does not use evidence and reasoning about energy ideas to support the claim.
The student selected answer choice B and wrote: "After each collision with the ground, the ball loses on average 0.76 m/s, but while the ball is in the air it only losses on average about 0.1 m/s (actual average: 0.0966666667 m/s)" "When colliding with the ground, the ball transfers energy to the ground, like hitting another ball in a game of pool, except the other ball is the size of the earth compared to the tennis ball size of your ball."	Score = 2 The response includes the correct claim and cites evidence to support the claim, but it does not use reasoning with science ideas or crosscutting concepts to link the evidence to the claim.
The student selected answer choice B and wrote: "when the ball hit the ground it lost about 0.7m/s in speed but when it went through the air it only lost about 0.1m/s in speed as the data table shows." "Energy cannot be created nor destroyed it can only be transferred. The energy in the ball transferred to the ground once the ball landed and then a small amount went through the air as it went back up and down again."	Score = 3 The response includes the correct claim, cites evidence, and uses a crosscutting concept, but it does not use reasoning to link the evidence to the claim.
The student selected answer choice B and wrote: "The speed lost from the bounce was around .25 where the speed lost from the air was only around .09" "Since the ball lost more speed after hitting the ground, that must represent how more energy	Score = 4 The response includes the correct claim, evidence, science ideas and reasoning, but does not use crosscutting

(kinetic) must be transferred into the ground than to the air." "The principle of energy conservation basically says that energy can not be created or destroyed but it can transform from one type to another. When the ball hits the ground the impact is much stronger than when the ball is falling in the air and causes a higher amount of energy to be transferred from the ball to the ground."	concepts about energy conservation.
The student selected answer choice B and wrote: "By looking at Columns 2 and 3 (right after the 1st bounce and right before the 2nd bounce) you can see that while in the air the ball goes from a speed of 3.32 meters/sec to 3.20 meters/ second in the 1st row. The speed lost was about 0.12 meters/second, this is the most energy that is lost while in the air. On the other hand, looking at Columns 1 and 2 (the speed before and after the 1st bounce) you can see that the speed goes from 4.07 meters/second to 3.32 meters/second in the 1st row. After hitting the ground the ball lost 0.75 meters/second of speed. It's obvious that after hitting the ground the ball lost a significant more amount of energy than the ball did while in the air."	Score = 5 The response includes all the elements in the rubric.

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