

ASPECT

Assessing Students' Progress on the Energy Concept

Bowling task: AP10-6 (MC) & AP36-5 (CR)

Elementary School – Energy Transfer by Forces

TASK OVERVIEW

Students are asked to think about what happens to energy when a bowling ball hits a pin. They make a prediction about how loud the sound will be if the ball is rolled faster and explain their prediction using energy ideas. They also analyze data on the speed of the ball before it hits the pin and the speed of the pin after it was hit and identify a pattern that they can use in constructing an explanation. The task ends with the students writing an explanation for why the ball slows down after it hits the pins.

TARGETED DCIs, SEPs, AND CCCs

Disciplinary core ideas

- PS3.A-4.1: The faster a given object is moving, the more energy it possesses.
- PS3.B-4.1: Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

Science & engineering practices

- SEP1-E.3: Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- SEP4-E.2: Analyze and interpret data to make sense of phenomena using logical reasoning.
- SEP6-E.1: Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).
- SEP6-E.2: Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation

Crosscutting concepts

- CCC1-E.3: Patterns can be used as evidence to support an explanation.
- CCC5-E.3: Energy can be transferred in various ways and between objects.

Related Performance Expectations

- 4-PS3-1: Use evidence to construct an explanation relating the speed of an object to the energy of that object. [*Assessment Boundary*: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]
- 4-PS3-3: Ask questions and predict outcomes about the changes in energy that occur when objects collide. [*Clarification Statement*: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [*Assessment Boundary*: Assessment does not include quantitative measurements of energy.]

TASK PERFORMANCE EXPECTATION

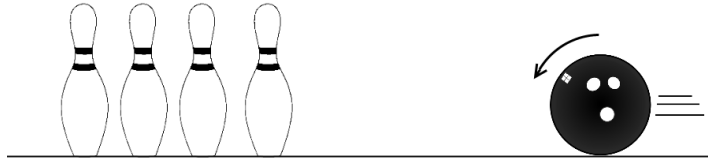
Predict the loudness of a collision between a bowling ball and a pin when the ball is traveling faster. *Analyze and interpret data* to find the pattern between the speed of the ball before the collision and the speed of the pin after the collision. *Construct an explanation* for the change in speed of the ball after the collision using ideas about energy transfer.

LINK TO ONLINE VERSION

<https://assess.bsos.org/i/test/586>

Task

Bowling is a game in which a person rolls a ball toward a set of pins and tries to knock the pins down.



When the ball hits the pins, the pins fall over, and a sound can be heard.



Bowling ball hitting pins (Photo by Tinou Bao on flickr / CC BY 2.0)

A person wants to find out how to make the loudest sound when the bowling ball hits the pins. She and her friend decide to do an experiment. She rolls the ball toward the pins. Her friend measures the speed of the ball and the loudness of the sound. She records the data in the table below. Then she rolls the ball again.

	Speed (miles per hour)	Loudness (decibels)
Try 1	10	80
Try 2	15	

-----Multiple-choice Version of #1-----

1. If the speed of the ball during Try 2 is 15 miles per hour, how loud do you think the sound will be on the second try? Why?
 - A. The loudness will be less than 80 decibels. The faster the ball is rolling, the less energy it can give to the air as sound when it hits the pins.

- B. The loudness will be more than 80 decibels. The faster the ball is rolling, the more energy it has and the more energy it can give to the air as sound when it hits the pins.
- C. The loudness will be more than 80 decibels. The faster the ball is rolling, the more sound it will make, but the sound is not related to energy.
- D. The loudness will be 80 decibels on the second try. The speed of the ball will not affect how loud the sound will be.

-----Constructed-response Version of #1-----

- 1a.** If the speed of the ball during Try 2 is 15 miles per hour, how loud do you think the sound will be on the second try?
- A. The loudness will be more than 80 decibels on the second try.
 - B. The loudness will be less than 80 decibels on the second try.
 - C. The loudness will be 80 decibels on the second try.
- 1b.** Support your prediction using what you know about the connection between energy, speed, and sound.

Next, the friends want to study the relationship between the speed of the bowling ball and the speed of the pins that are knocked down. They use one pin and an eight-pound bowling ball. They measure the speed of the ball right before it hits the pin and the speed of the pin right after it is hit. They roll the ball three separate times and record the data in the table below.

Speed of the ball right before hitting pin (miles per hour)		Speed of the pin right after being hit (miles per hour)	
Try 1	10	Try 1	9
Try 2	15	Try 2	14
Try 3	18	Try 3	16

- 2a.** What pattern do you notice in the data in the table above?
- A. The faster the ball is moving before it hits the pin, the faster the pin will move after it is hit.

- B. The faster the ball is moving before it hits the pin, the slower the pin will move after it is hit.
- C. The pin's speed is not affected by how fast the ball is moving before it hits the pin.

-----Multiple-choice Version of #2b-----

- 2b. Which of the following explains the pattern you noticed in the data?
- A. As the ball rolls, it uses energy. The faster the ball rolls, the more energy it uses. This causes less energy to be given to the pin when the ball hits it, which makes the pin move slower the faster the ball rolls.
 - B. The faster the ball rolls, the more energy it has. If the ball rolls faster, more energy will be given to the pin when the ball hits it. This will cause the pin to move faster the faster the ball rolls.
 - C. The energy the pin has after being hit by the ball comes from the person rolling the ball. So, the speed of the pin right after being hit depends on who rolls the ball not on how fast the ball is moving before it hits the pin.
 - D. The speed of the pin right after being hit depends on how hard the pin is hit not on how fast the ball is moving before it hits the pin.

-----Constructed-response Version of #2b-----

- 2b. Explain the pattern you noticed in the data using what you know about the relationship between energy and speed.

-----Multiple-choice Version of #3-----

3. The friends notice that the ball slows down after it hits the pin. Which of the following explains why the ball slows down after it hits the pins?
- A. The ball slows down because it has less energy after it hits the pin. Energy is moved from the ball to the pin and the air when the ball hits the pin. The increase in motion of the pin and the sound are evidence that energy was moved.
 - B. The ball slows down because it has less energy after it hits the pin. Energy is moved only from the ball to the air when the ball hits the pin. The sound is evidence that energy was given to the air. The motion of the pin is not related to energy.
 - C. The ball slows down because it has less energy after it hits the pin. Energy is moved only from the ball to the pin when the ball hits it. The motion of the pin

is evidence that energy was given to the pin. The sound is not related to energy.

- D. The ball slows down because it has less force after it hits the pin. A force, not energy, is moved from the ball to the pin when the ball hits the pin. This force is changed into energy. The increase in motion of the pin and the sound are evidence that the force was changed into energy.

-----Constructed-response Version of #3-----

3. The friends notice that the ball slows down after it hits the pin. Use energy ideas to explain why the ball slows down after it hits the pin. Be sure to write about the observations and include ideas about how energy can move from place to place.

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

QUESTION 1

If the speed of the ball during Try 2 is 15 miles per hour, how loud do you think the sound will be on the second try?

- A. The loudness will be more than 80 decibels on the second try.
- B. The loudness will be less than 80 decibels on the second try.
- C. The loudness will be 80 decibels on the second try.

Support your prediction using what you know about the connection between energy, speed, and sound.

LEARNING GOAL

Learning Performance

- Select the correct prediction about the loudness of the sound that will be made when the ball is traveling faster and hits the pins and write (CR) or select (MC) an explanation that supports the prediction using ideas about energy transfer.

Targeted DCIs, SEP, and CCC

- PS3.A-4.1: The faster a given object is moving, the more energy it possesses.
- PS3.B-4.1: Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- SEP1-E.3: Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- CCC5-E.3: Energy can be transferred in various ways and between objects.

SCORING RUBRIC

Ideal Response

The loudness will be greater than 80 decibels. The ball is moving faster in Try 2 than it is in Try 1. The faster the ball is rolling the more energy it has, and the more energy it can give to the air as sound when it hits the pins.

Elements of a Correct Response

Categories	Elements
Student selects the correct prediction	A. The loudness will be more than 80 decibels on the second try.
Student either states or uses a general science idea	<ul style="list-style-type: none">• The faster an object is moving, the more energy it has (i.e., the faster the ball rolls the more energy it has). [<i>links speed and energy</i>]• When objects collide, energy can be transferred from one object to another [resulting in a change in motion] (i.e., the ball transfers energy to the pin when it hits the pin). [<i>links collisions and energy transfer</i>]• Sound results from the transfer of energy [to the surroundings] during a collision (i.e., the sound made when the ball hits the pin and transfers energy). [<i>links sound and energy transfer</i>]

	<ul style="list-style-type: none"> ○ <u>Note</u>: At the elementary level, students do not have to be explicit about the fact that the sound is energy being transferred to the air/surroundings. However, they do need to explicitly link sound to the transfer of energy.
Student uses reasoning to link their prediction and science ideas	<ul style="list-style-type: none"> • The faster the ball rolls, the more energy it can transfer as sound, resulting in a louder sound on the second try. (4) <p>Note: Students reasoning must be clear and coherent.</p>
Student does not mention energy but has productive ideas	<ul style="list-style-type: none"> • The faster the ball moves, the more force it will exert on the pins. [<i>links speed and force</i>] • The faster the ball rolls, the louder the sound will be. [<i>links speed directly to sound</i>] • The more force the ball exerts on the pins, the louder the sound will be. [<i>links force directly to sound</i>]
OR	
Student selects the correct response to the multiple-choice version	B. The loudness will be more than 80 decibels. The faster the ball is rolling, the more energy it has and the more energy it can transfer to the air as sound when it hits the pins.

Sample Student Responses

	Student response	Scoring description
1	Student selected B and wrote "The sound of the bowling ball hitting the pins will be less because of the speed you are throwing the ball will take away energy from the bowling ball."	Score = 0 The student selected the incorrect answer and did not correctly link ideas about energy, speed, and sound.
2	Student selected A and wrote "It will be louder because when the ball is going faster its louder."	Score = 1 The student gets a point for selecting the correct answer but no other points because their response only includes the idea that the faster the ball

		rolls the louder the sound will be. It does not connect ideas about speed and sound with ideas about energy.
3	Student selected A and wrote "When energy increases so does the speed and when the ball is going faster when it hits the pins it is going to make a louder sound."	Score = 2 This response includes the science idea that links energy and speed, but the reasoning is not clear and coherent.
4	Student selected A and wrote "I think that the sound of the ball hitting the pins will be louder, because the amount of kinetic energy transferred from the ball to the pins is greater. Because the speed of the ball is moving 5 mph faster than try 1, the impact of the ball hitting the pins will allow for an increase in sound."	Score = 3 This response includes reasoning with science ideas that support the correct prediction.

QUESTION 2

What pattern do you notice in the data in the table above?

- A. The faster the ball is moving before it hits the pin, the faster the pin will move after it is hit.
- B. The faster the ball is moving before it hits the pin, the slower the pin will move after it is hit.
- C. The pin's speed is not affected by how fast the ball is moving before it hits the pin.

Explain the pattern you noticed in the data using what you know about the relationship between energy and speed.

LEARNING GOAL

Learning Performance

- Analyze data in a table to find the pattern between the speed of the ball before the collision and the speed of the pin after the collision and write (CR) or select (MC) an explanation for the pattern observed in the data using ideas about energy.

Targeted DCIs, SEP, and CCC

- PS3.A-4.1: The faster a given object is moving, the more energy it possesses.
- PS3.B-4.1: Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- SEP4-E.2: Analyze and interpret data to make sense of phenomena using logical reasoning.
- SEP6-E.1: Construct [or evaluate] an explanation of observed relationships (e.g., the distribution of plants in the back yard).
- CCC5-E.3: Energy can be transferred in various ways and between objects.
- CCC1-E.3: Patterns can be used as evidence to support an explanation.

SCORING RUBRIC

Ideal Response

The faster the ball rolls, the more energy it has. If the ball rolls faster, it will have more energy that it can give to the pin when the ball hits the pin. This will cause the pin to move faster.

Elements of a Correct Response

Categories	Elements
Student selects the correct pattern	A. The faster the ball is moving before it hits the pin, the faster the pin will move after it is hit.

Student either states or uses a general science idea	<ul style="list-style-type: none"> The faster an object is moving, the more energy it has (the faster the pin or ball moves the more energy it has). [<i>links speed and energy</i>] When objects collide, energy can be transferred from one object to another [resulting in a change in motion] (i.e., the ball gives energy to the pin when it hits the pin). [<i>links collisions and energy transfer</i>]
Student uses reasoning to link science ideas to the pattern	<ul style="list-style-type: none"> The faster the ball rolls, the more energy it has, and the more energy it will give to the pins when it hits it, causing the pin to move faster.
Student does not mention energy but has productive ideas	<ul style="list-style-type: none"> The faster an object is moving, the more force it can exert on another object (i.e., the faster the ball moves the more force it will exert on the pins). (Alternative science idea) [<i>links speed and force</i>]
OR	
Student selects the correct response to the multiple-choice version	B. The faster the ball rolls, the more energy it has. If the ball rolls faster, more energy will be given to the pin when the ball hits it. This will cause the pin to move faster.

Sample Student Responses

Student response	Scoring description
Student selected B and wrote "i notice that the faster the ball is it affects the pins falling"	Score = 0 This student chose the incorrect answer and did not correctly describe the relationship between energy, the speed of the ball, and the speed of the pin after it was hit.

<p>Student selected A and wrote</p> <p>“Every time the ball was going faster the pins also went faster.”</p>	<p>Score = 1</p> <p>This student received a point for selecting the correct pattern, but their response simply describes the pattern but does not explain it using science ideas.</p>
<p>Student selected A and wrote</p> <p>“When hitting something movable with enough force, the kinetic energy flows from the first object into the object being hit and transfers.”</p>	<p>Score = 2</p> <p>This student received a point for selecting the correct pattern, and their response includes the science idea that energy is transferred during collisions, but it does not link that science idea to the pattern they see.</p>
<p>Student selected A and wrote</p> <p>“The reason the pins moved quicker when the ball was hitting it at a faster speed is because there is more energy getting transferred to the pin which causes it to move faster.”</p>	<p>Score = 3</p> <p>This response includes all the elements of a correct response.</p>

QUESTION 3

The friends notice that the ball slows down after it hits the pin. Use energy ideas to explain why the ball slows down after it hits the pin. Be sure to write about the observations and include ideas about how energy can move from place to place.

LEARNING GOAL

Learning Performance

- Write (CR) or select (MC) an explanation for the observation of a ball slowing down using ideas about energy transfer.

Targeted DCIs, SEP, and CCC

- PS3.A-4.1: The faster a given object is moving, the more energy it possesses.
- PS3.B-4.1: Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- SEP6-E.2: Use evidence (e.g., measurements, observations, patterns) to construct [or evaluate] or support an explanation.
- CCC5-E.3: Energy can be transferred in various ways and between objects.

SCORING RUBRIC

Ideal Response

The ball slows down because when the ball hits the pin, energy is transferred from the ball to the pin and from the ball to the air which means that the ball has less energy after hitting the pin. I know energy has been transferred from the ball to the pin and air because the pin starts to move when the ball hits it and because a sound is heard when the ball hits the pin. Both the increase in motion of the pins and the sound indicate an increase in energy, which had to come from somewhere else (i.e., the ball).

Elements of a Correct Response

Categories	Elements
Student makes a claim that answers the question	<ul style="list-style-type: none"> • The ball slows down because the ball transfers energy to the pin and/or the air. <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> • The ball slows down because the ball has less energy after hitting the pin. <p><u>Note:</u> “The ball slowing down because” part of the claim can be implied.</p>
Student lists evidence of energy changes	<ul style="list-style-type: none"> • The pin starts moving (falls down) after it was hit. • A sound was heard when the ball hit the pin.
Student either states or uses a	<ul style="list-style-type: none"> • The faster/slower an object moves, the more/less energy it has (i.e., the faster the pin moves the more energy it has, or

<p>general science idea</p>	<p>the ball has less energy when it is moving slower). [<i>links speed and energy</i>]</p> <ul style="list-style-type: none"> • When objects collide, energy can be transferred from one object to another [resulting in a change in motion] (i.e., the ball transfers energy to the pin when it hits the pin). [<i>links collisions and energy transfer</i>] <ul style="list-style-type: none"> ○ <u>Note</u>: At the elementary level, students do not have to explicitly mention energy being transferred from the ball to the pin. Using wording like “the pin takes on the energy” or “the ball loses energy when it hits the pin” is acceptable. • During a collision, some energy is transferred to the air and sound is produced (i.e., the sound heard when the ball hit the pin results from the transfer of energy from the ball to the pin). [<i>links sound and energy transfer</i>] <ul style="list-style-type: none"> ○ <u>Note</u>: At the elementary level, students do not have to be explicit about the fact that the sound is energy being transferred to the air/surroundings. However, they do need to explicitly link sound to the transfer of energy.
<p>Student uses reasoning to link evidence and/or science ideas to the claim</p>	<ul style="list-style-type: none"> • The ball transferred energy to the pin and air as indicated by the increased speed of the pin and the sound heard during the collision, which means the ball has less energy and will therefore slow down. [<i>links evidence, science principles, and the claim</i>] <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> • Energy is transferred during collisions which means the ball transfers energy to the pin, so the ball has less energy and will therefore slow down. [<i>links science principles to the claim</i>]. <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> • The fact that the pins started moving and a sound was heard means that the ball has less energy and will therefore slow down. [<i>links evidence to the claim</i>] <p><u>Note</u>: Students reasoning must use logic and be clear and coherent. For example, simply stating the evidence after the</p>

	claim would not get a reasoning point. There must be some connection between the two.
OR	
Student selects the correct response to the multiple-choice version	A. The ball slows down because it has less energy after it hits the pin. Energy is moved from the ball to the pin and the air when the ball hits the pin. The increase in motion of the pin and the sound are evidence that energy was moved.

Sample Student Responses

Student response	Scoring description
"Well the ball goes fast when its rolling and when the ball hits the pins I think they have a big impact and the ball goes slower."	Score = 0 This response repeats the observation and does not use science ideas to explain why the ball slows down.
"it slows down because the energy has transferred"	Score = 1 This response only includes a claim.
"The ball slows down since it hit the pin which transferred the energy to it."	Score = 2 This response includes a claim and a science idea, but no evidence or reasoning.
"Energy is transferred from the ball to the pin so the ball doesn't have as much energy as it did before so it will slow down."	Score = 3 This response includes a claim, science idea, and reasoning, but does not include evidence.
"The ball slowed down after it hit the pin because the energy that the ball had transferred to the pins. You can see this happen because after the pin got hit it was able to move."	Score = 4 This response includes elements from all four categories in the rubric.

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