ASPECt
Assessing Students' Progress on the Energy Concept

Catapult: AP12-5 (MC) & AP38-6 (CR)

Middle School - Energy Transfer by Forces

TASK OVERVIEW

Students are presented with a scenario in which a student is planning on building a catapult. The task simplifies the scenario by having the students consider a single wooden stick and a ball. First, the students think about the changes in kinetic energy of the ball and in the potential energy of the stick. They construct or select bar graphs to represent the changes and explain where the kinetic energy of the ball if coming from. Then, the students think about how to design an experiment to study the effect the amount the stick is bent has on the height the ball travels when shot up by the stick. They identify what they would change during each trial and why they should use the same ball in each trial. Finally, the students predict under what conditions the ball will go the highest and explain their prediction using ideas about energy transfer.

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. (Specific to this task: when an elastic object is deformed its potential energy increases.)

- 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.

Science & engineering practices

- SEP3-M.1: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships
- SEP6-M.4: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- SEP7-M.3: Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem

Crosscutting concepts

- CC5-M.3: Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
- CC5-M.4: The transfer of energy can be tracked as energy flows through a designed or natural system.
- CC2-M2: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Related Performance Expectations

- MS-PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [*Clarification Statement*: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary*: Assessment does not include calculations of energy.]

TASK PERFORMANCE EXPECTATION

Construct bar graphs to represent the change in kinetic and potential energy and *design an experiment to determine* how the amount of the stick is bent affects how

high the ball can be shot into the air. *Construct an argument* for which trial will result in the ball traveling the highest using cause and effect relationships and ideas about energy.

LINK TO ONLINE VERSION

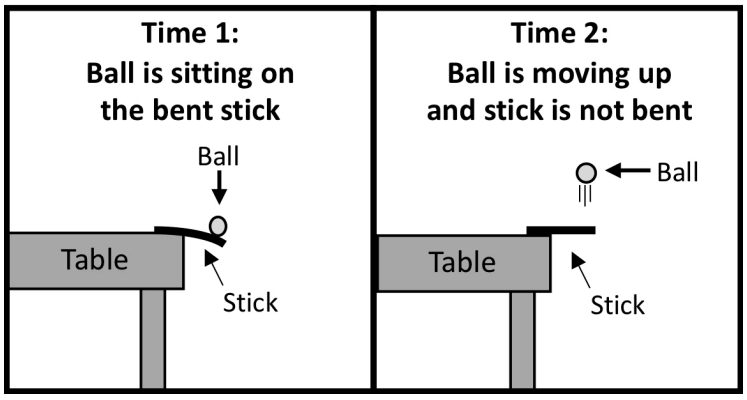
http://assess.bscs.org/i/test/592

Task

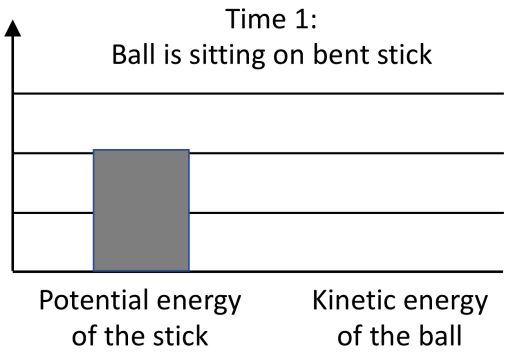
A student wants to build a catapult. A catapult is a device that can be used to launch an object into the air. To learn more about how catapults work, he makes a simple catapult. He holds a flat wooden stick at the edge of a table, places a small ball at the end of the stick, and pulls the end of the stick down before releasing it. The video below shows what happened.

http://assess.bscs.org/items/media/uploads/image/ASPECt_3D/popsicle_stick_catapult_1_-_Copy.mp4

The figure below shows a diagram of the ball and stick when he bends the stick (Time 1) and when he lets go (Time 2). He wants to use what he knows about energy to explain how the catapult works and figure out how to get the ball to go as high as it can.

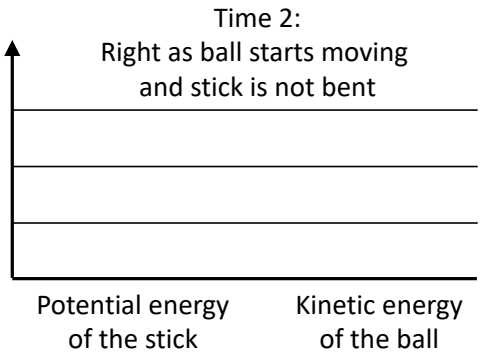


1. He thinks about how the kinetic energy of the ball and the potential energy of the stick change when the ball is shot into the air. The bar graph below shows the amount of energy the stick and ball have while the ball is sitting on the bent stick (Time 1).



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

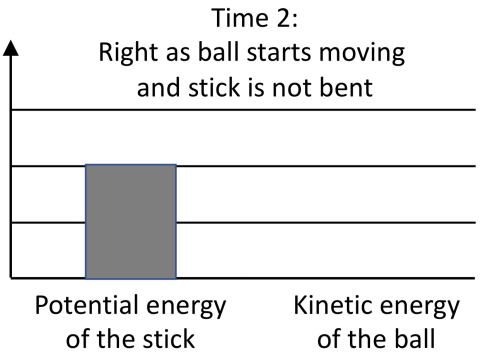
Create a bar graph to show the amount of energy the stick and ball have just as the ball starts moving up and the stick is no longer bent (Time 2).



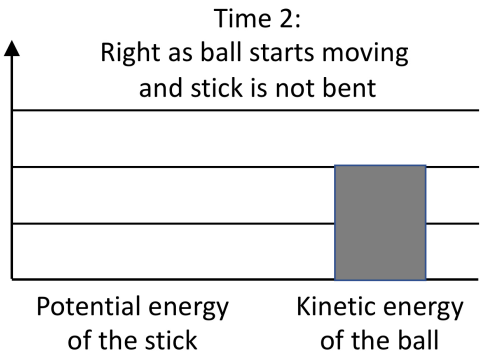
----------Multiple-choice Version of #1----------

Which of the following bar graphs shows the amount of energy the stick and ball have just as the ball starts moving up and the stick is no longer bent (Time 2)?

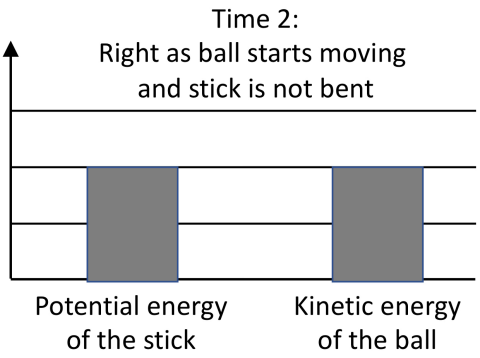
A.



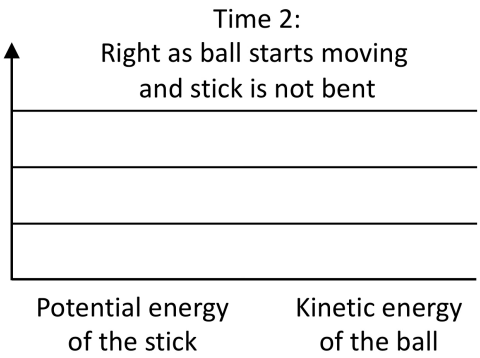
B.



C.



D.



2. Where does the ball get the energy to shoot up into the air when the popsicle stick is released? Explain your answer using ideas about energy transfer and evidence from the video.

After testing his simple catapult, he wants to find out if the amount the stick is bent could affect how high the ball goes into the air. He designs a simple experiment to help him answer that question. He thinks he should use the same stick and ball throughout the experiment.

3. Why is it important that the ball be the same throughout the experiment?

   A. By using the same ball, you can learn which type of ball goes higher when shot into the air.

   B. By using the same ball, you can learn how the amount the stick is bent affects how high you can shoot the ball into the air.

   C. By using the same ball, you can learn two things. You can learn which type of ball goes higher when shot into the air. You can also learn how the amount the stick is bent affects how high you can shoot the ball into the air.

   D. It is NOT important for the same ball to be used. Even if you use different balls throughout the experiment, you can still learn how the amount the stick is bent affects how high you can shoot a ball into the air.

4. What variable should he change during the experiment?

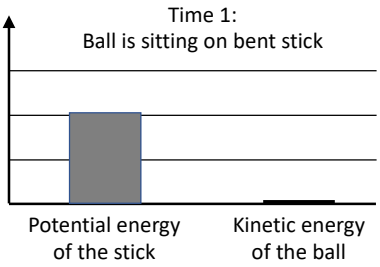
5. If you were to do this experiment, under what condition would you expect the ball to go the highest?

6. Why do you think the ball would go the highest under this condition? Explain using what you know about energy.

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

QUESTION 1

He thinks about how the kinetic energy of the ball and the potential energy of the stick change when the ball is shot into the air. The bar graph below shows the amount of energy the stick and ball have while the ball is sitting on the stick and the stick is bent (Time 1).



Create a bar graph to show the amount of energy the stick and ball have just as the ball starts moving up and the stick is no longer bent (Time 2).

LEARNING GOAL

Learning Performance

- Draw (CR) or select (MC) bar graphs that correctly represent the kinetic energy change and potential energy change when the ball goes from sitting on the bent popsicle stick to moving up into the air.

Targeted DCIs, SEP, and CCC

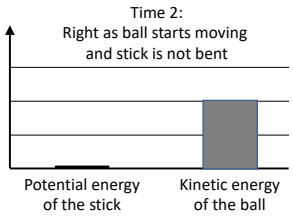
- PS3.A-M.1: Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- PS3.A-M.2: A system of objects may also contain stored (potential) energy, depending on their relative positions.
- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.

SCORING RUBRIC

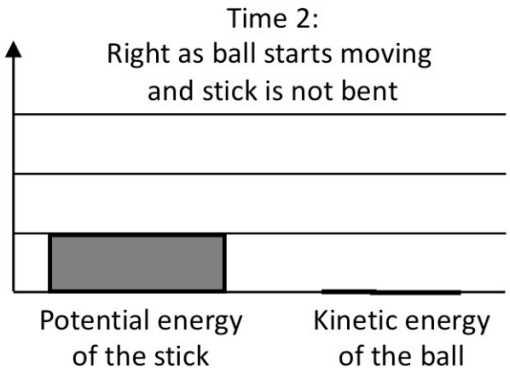
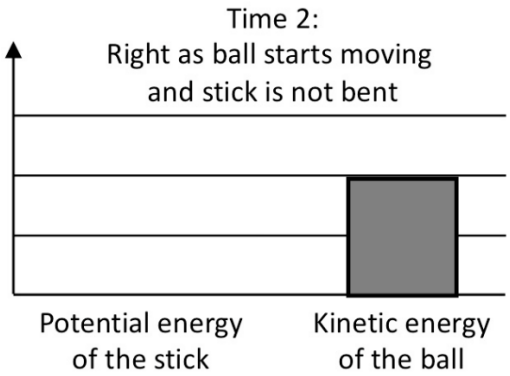
Ideal Response

The student draws a bar graph that indicates that the ball has more kinetic energy at Time 2 than at Time 1 and the stick has less potential energy at Time 2 than at Time 1.

Elements of a Correct Response

Categories	Elements
Student draws bars on the graph	• For the potential energy of the stick, a bar of zero height (or no bar) AND • For the kinetic energy of the ball, a bar of some height Note: If a student draws a bar for the potential energy of the stick, the important thing is that the bar for Time 2 must be shorter than the bar for Time 1. (These students may have chosen a different zero point for potential energy.)
OR	
Student selects the correct graph for the multiple-choice version	B. 

Sample Student Responses

Student response	Scoring description
	Score = 0 The graph indicates a decrease in potential energy but not an increase in kinetic energy.
	Score = 1 The graph correctly illustrates the amount of energy the stick and ball have when the ball is moving and the stick is no longer bent.

QUESTION 2

Where does the ball get the energy to shoot up into the air when the popsicle stick is released? Explain your answer using ideas about energy transfer and evidence from the video.

LEARNING GOAL

Learning Performance

- Explain that the ball gets energy from the popsicle stick when the popsicle stick pushes it.

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.B-M.1: When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- SEP6-M.4: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- CC5-M.4: The transfer of energy can be tracked as energy flows through a designed or natural system.

SCORING RUBRIC

Ideal Response

The ball gets energy from the stick. When the popsicle stick is released, the ball starts to move. This means an increase in motion energy. Therefore, there must be another change in energy at the same time. This change is the decrease in potential energy of the stick when it goes from being bent to being straight. The energy was transferred to the ball when the stick pushed the ball upward.

Elements of a Correct Response

Categories	Elements
Student makes a claim about the energy source	• The ball gets energy from the stick.
Student cites evidence	• The stick goes from being bent to being straight.
Student either states or uses a general science idea	• Bending an [elastic] object increases the potential energy on the object (i.e., the more the stick is bent the more energy it has). [*links bending and energy*] • Energy is transferred when one object exerts a force on another object (i.e., the stick pushes the ball transferring energy to the ball). [*links force and energy transfer*] • When the motion energy of an object changes, there is inevitably some other change in energy at the same time (i.e., the motion energy of the ball changed and thus there

	must have been changes in energy elsewhere) [*conservation*]
Student uses a crosscutting concept	• Energy may take different forms (e.g., the potential energy of the stick is transformed into the kinetic energy of the ball). [*forms of energy*] • The transfer of energy can be tracked through a system (e.g., energy is transferred from the stick to the ball or the energy came from the stick, or the stick gave the ball energy). [*energy can be tracked*]
Student uses reasoning to link evidence, science ideas, and/or crosscutting concepts to the claim	• The stick exerts a force on the ball when it is let go and the force transfers energy from the stick to the ball. OR • The stick decreases in energy because it goes from being bent to being straight and because the stick interacted with the ball, the energy is transferred from the stick to the ball.

Sample Student Responses

Student response	Scoring description
"the ball gets kinetic energy from movement and that why it goes so high."	Score = 0 The response includes the misconception that energy is created from movement.
"It gets the energy from the stick. When the stick is pushed down on the ball launches off of the energy given."	Score = 1 The response includes the correct claim but no other rubric elements.
"When the stick is released the stick gives motion energy to the ball."	Score = 2 The response includes the correct claim and the crosscutting concept about tracking energy.

“When the stick bent the ball when into the air. The stick had force on the ball which gave it the energy to go up. That is how I think the ball got the energy because of the force the stick had on the ball.”	Score = 3 The response includes a claim, science ideas about transferring energy by forces, and reasoning.
“The stick transferred kinetic energy to the ball. When the stick was pulled back it got potential energy and transferred energy.”	Score = 4 The response does not cite the evidence.
“The ball gets its energy form the potential energy from the bent stick. Once the stick is released there is a energy transfer from the potential energy of the stick to the kinetic energy of the ball which makes it "shoot" up into the air.”	Score = 5 The response includes all the elements in the rubric.

QUESTION 3

Why is it important that the ball be the same throughout the experiment?

A. By using the same ball, you can learn which type of ball goes higher when shot into the air.

B. By using the same ball, you can learn how the amount the stick is bent affects how high you can shoot the ball into the air.

C. By using the same ball, you can learn two things. You can learn which type of ball goes higher when shot into the air. You can also learn how the amount the stick is bent affects how high you can shoot the ball into the air.

D. It is NOT important for the same ball to be used. Even if you use different balls throughout the experiment, you can still learn how the amount the stick is bent affects how high you can shoot a ball into the air.

LEARNING GOAL

Learning Performance

- Select the correct reason for using the same ball in each trial of an experiment to determine how the amount the stick is bent affects how high the ball can be shot into the air.

Targeted DCIs, SEP, and CCC

- SEP3-M.1: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Students select the correct answer	B. By using the same ball, you can learn how the amount the stick is bent affects how high you can shoot the ball into the air.

QUESTION 4

What variable should he change during the experiment?

LEARNING GOAL

Learning Performance

- State the independent variable in an experiment to study how the amount the stick is bent affects how high the ball can be shot into the air.

Targeted DCIs, SEP, and CCC

- SEP3-M.1: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed

to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

SCORING RUBRIC

Ideal Response

He should change the amount the stick is bent

Elements of a Correct Response

Categories	Elements
Student states the independent variable	• The amount the stick is bent. OR • The amount of force applied to the stick. OR • The potential energy of the stick.

Sample Student Responses

Student response	Scoring description
"The variable that he should change is where he does it. He should maybe do it out side so the ball could get more air when it goes up into the air."	Score = 0 The response does not describe the correct independent variable.
"He should change the depth of which the stick is bent to see how it can affect the height at which the ball is shot up when released."	Score = 1 The response describes the correct independent variable.

QUESTIONS 5 & 6

If you were to do this experiment, under what condition would you expect the ball to go the highest?

Why do you think the ball would go the highest under this condition? Explain using what you know about energy.

LEARNING GOAL

Learning Performance

- Make a prediction about which condition will result in the ball going the highest after it is released. Justify the prediction about the conditions necessary to get the ball to go the highest using ideas about energy.

Targeted DCIs, SEP, and CCC

- PS3.A-M.2: A system of objects may also contain stored (potential) energy, depending on their relative positions.
- 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.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.
- CC2-M2: Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- CC5-M.4: The transfer of energy can be tracked as energy flows through a designed or natural system.
- CC5-M.3: Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).

SCORING RUBRIC

Ideal Response

The ball would go the highest when the stick is bent the most.

The farther the popsicle stick is bent, the more potential energy it will have and the more energy it can transfer to the ball when let go. Receiving more energy will cause the ball to go higher.

Elements of a Correct Response

Categories	Elements
Student makes the correct prediction	• The ball would go the highest when the stick is bent the most.

Student either states or uses a general science idea	• Bending an [elastic] object increases the potential energy on the object (i.e., the more the stick is bent the more energy it has). [*links bending and energy*] • Energy is transferred when one object exerts a force on another object (i.e., the stick pushes the ball transferring energy to the ball). [*links force and energy transfer*]
Student uses a crosscutting concept	• The transfer of energy can be tracked through a system (e.g., from the stick to the ball). [*energy can be tracked*] • Energy may take different forms (e.g., the potential energy of the stick is transformed into the kinetic energy of the ball). [*forms of energy*]
Student uses reasoning to link science ideas and/or crosscutting concepts to their prediction	• The more the stick is bent, the more energy it has that can be transfer to the ball when released. The more energy the ball receives from the stick, the higher it will go.

Sample Student Responses

Student response	Scoring description
"The highest you can shoot a ball into the air amount how high you can shoot." "By using the same ball you can learn which type of ball goes higher when shot into the air."	Score = 0 The response does not include any of the elements in the rubric.
"When you bend the stick because there is more force around it." "The energy from the stick pushes the ball then the gravity pulls the ball back to the earth."	Score = 1 The response includes the correct prediction, but it doesn't include a well-reasoned explanation, i.e., when the stick is bent the most the ball will go the highest because more energy is transferred.

"when the stick is bent back the most" "because there is more energy in the stick when you bend it back farther."	Score = 2 The response includes the correct prediction and science ideas about potential energy.
"When the stick is bent at its farthest point and let go before the stick can snap." "I think the ball would go the highest in this condition because the farther the stick is bent the more engery is created so the more engery is transferd to the ball making it higher."	Score = 3 The response includes the correct prediction and science ideas and crosscutting concepts, but the response is not well reasoned and includes the misconception that energy is created.
"When the stick is bent the most." "It would go higher because there is more energy that is built up during the bending of the stick, that means that there is more energy to transfer to the ball."	Score = 4 The response includes all the elements in the rubric.

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