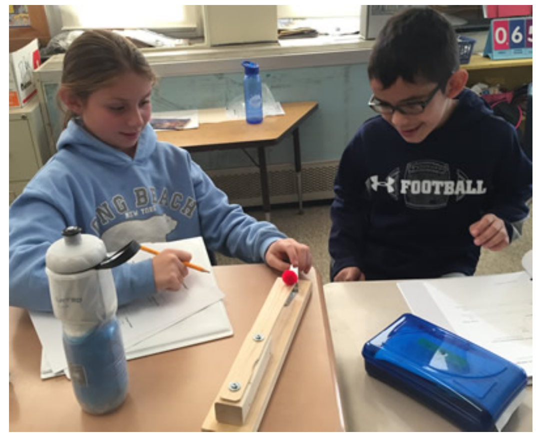
Motion Energy Curriculum Unit Overview



Elementary students easily relate motion and energy; they are likely to describe another child or a car that is speeding by as having a lot of energy, and there may have been times when they themselves have been told that they have "too much energy" when they exceed the indoor speed limit at home or at school. This makes *motion energy* a natural starting place for a sequence of learning activities about energy for elementary students.

Does an object or person have to be speeding by to have motion energy? No. Only things that are stationary have no motion energy. The snail that is barely moving has motion energy. (Yes, because Earth is flying through space, everything on Earth has motion energy, but we will define motion as relative to a point on our planet.) We can quantify motion energy. In this unit we limit that quantification to describing objects as having *no* motion energy, a *little* motion energy, or a *lot* of motion energy. The faster the snail goes, the more motion energy it has.

Returning to that speeding child, can we actually see motion energy? No. Energy itself is not visible, so we depend on observable clues to inform us of the presence of energy. In the case of motion energy, we use speed as an indicator to tell us if an object has gained or lost energy.

The Energy Tracking Lens
The Energy Tracking Lens is a framework that is formally introduced to students in Motion Investigation 3B. It is a set of questions that guides students through the process of "telling the energy story," something they are asked to do throughout this unit. The Energy Tracking Lens is applicable to all systems, both simple and complex. A copy of the Energy Tracking Lens is included on the first page of each Student Notebook.

Representations
The Motion Energy Unit introduces a set of representations that become important tools for students as they reason about their ideas about the flow of energy through a system. Energy Bars, Energy Cubes, annotated drawings, and other representations also help students share their ideas with others and receive feedback.

In the Classroom

This sequence of five investigations on motion energy starts with a short video montage and discussion to elicit students' initial ideas about energy. Students then roll small balls along a track at different speeds, an activity that supports the idea that motion energy is not just present or not, but exists along a continuum of magnitudes. In Investigation 2, students create collisions between balls on that track. In addition to being engaging, this helps develop the idea that motion energy can be transferred from one object to another, and that an energy gain in one place is always coupled with an energy loss somewhere else. The last three investigations in this unit add experiences with energy *transformation*. As students explore *elastic* objects—objects that spontaneously return to their original shape after being deformed (think rubber band, diving board)—they discover that the *elastic energy* of a deformed object transforms into motion energy once the deformed object is released. These key ideas about energy transfer, energy transformation, and the coupling of energy gains and losses, as well as students' early work with representations of energy flow through a system, set the foundation for their work with energy in other contexts.

Focus on Energy: Preparing Elementary Teachers to Meet New Science Standards.
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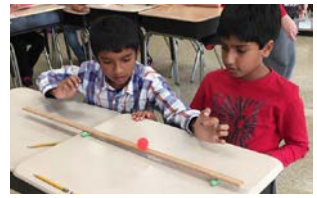
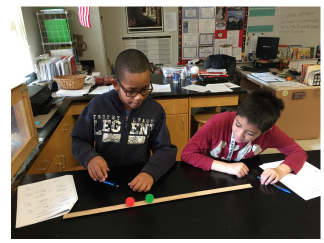
Motion Energy Unit – Sequence of Activities

1. What can motion tell us about energy?			
Activity	**Learning Targets Introduced**	**Representations**	**Image of Activity**
Rolling ball	• Energy cannot be directly seen or measured. • All moving objects have motion energy. • Speed is the indicator of how much motion energy an object has. If an object's speed increases or decreases, its motion energy has increased or decreased.	Cards with symbols (no motion, some motion, lots of motion)	
2. Can a ball cause another ball to move AND not lose any of its own energy?			
Colliding balls Quick Check	• Energy can move from one object to another object; this is called energy transfer. • Motion energy can be transferred between objects through pushes, pulls, hits, or collisions. Stronger interactions (e.g., bigger hits) transfer more motion energy. • Energy changes take place in multiples; whenever there is a loss of energy somewhere, there must be a gain in energy somewhere else (and vice versa). • A drawing or representation (such as energy bars) can show changes in the amount of energy an object has.	Energy bars	
3a. Can a paint paddle gain and lose energy?			
Paint paddle pom-pom launcher	• An elastic object is any object that returns to its original shape after being deformed (bent, twisted, stretched, squeezed, etc.) • Deformation of an elastic object is the indicator of the object's elastic energy. If an elastic object's deformation increases or decreases, its elastic energy has increased or decreased. • When energy changes from one form to another, this is called energy transformation. • Motion energy can be transformed into elastic energy (and vice versa).	Energy bars	
3b. What's the energy story of the paint paddle and pompom?			
Paint paddle pom-pom launcher	• Energy cubes can be used to reason about energy flows and forms.	Sketches, Energy cubes	
4. What's the energy story of the propeller?			
Rubber band and propeller Wrap Up Probe	• The Energy Tracking Lens questions, "Where does the energy come from?" and, "Where does the energy go?" provide a useful way of thinking about energy flow in any scenario. • Drawings and representations help reason about energy flow and transformation in a scenario.	Student sketches, Energy cubes	

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Materials for the Motion Energy Curriculum Unit

Materials are listed for a classroom of 24 students split into 12 pairs. Your classroom may require modifications of this list.

Source	Item	Number
Available in Kit Kits can be ordered from: Sempco 51 Lake Street #7 Nashua, NH 03060 Phone: 603-889-1830 FAX: 603-889-1766 Web: http://www.sempcoinc.com Email: info@sempcoinc.com	Wooden track, 30"	12
	Clay, 1 lb.	1
	Rubber ball, 1¼ ", color-1	13
	Rubber ball, 1¼ ", color-2	13
	Foam can insulator	1
	Paint paddle, heavy duty	1
	Springboard	12
	Pompom, 1"	14
	Cube, transparent, 25-mm (teacher Energy Cubes)	6
	Cube, transparent, 18-mm (student Energy Cubes)	72
	Dot label, ¾" (red, blue, yellow, green), 420 per set (for Energy Cubes)	1
	Propeller-elastic band system-teacher (with PVC tube, cork and brake stick)	1
	Propeller-elastic band system-student	12
	Wind-up toy, "Sparklz"	1
Available on the Focus on Energy Website	Motion Energy Notebook	24
	Motion Notecards (3 cards per set)	12
Provided by Classroom	Markers, large sheets of paper or white board (for classroom and each pair of students)	13
	Empty 12-ounce soda can	1
	A collection of elastic objects, e.g., rubber band or exercise band, spring, pop up or wind-up toy	

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Motion Energy – Investigation 1

What can motion tell us about energy?

Plan Investigation 1

The concept of energy is a challenging one. We hear the word frequently, in very different contexts, but we can't see it. When we say that a child is full of energy, is that the same stuff as the energy of a flashlight battery, or of a granola bar, or the energy that comes from the sun? Well, yes. Does it seem strange that we use the same word for all of that stuff? Yes. Although there are many forms of energy (including electrical energy, heat energy, light energy, motion energy, and chemical energy) and many different ways in which the presence of energy is measured (e.g., calories, kilowatt-hours, BTU's, joules, etc.), ultimately, it's all the same. Energy is energy. It can be transferred from one object to another; and it can be changed from one *form* to another (transformed).

This sequence of five investigations focuses on *motion energy* and provides some of the foundational ideas that prepare students for moving on to sequences that address thermal energy and electrical energy.

In this first investigation students share ideas about what the word energy means to them, watch a short video that includes 12 situations where energy is present in various forms, and then share ideas about what they notice that suggests the presence of energy. They can't see energy directly, but they can observe evidence of the presence of various forms of energy (motion energy; thermal energy; light energy.) Although the video includes examples of several forms of energy, students quickly move on to explore *motion energy* by rolling a small rubber ball along a track. They are introduced to the concept that an object can have different amounts of motion energy, depending on its speed.

Learning Targets Introduced in this Investigation

- Energy cannot be seen or directly measured.
- All moving objects have motion energy.
- Speed is the indicator of how much motion energy an object has. If an object's speed increases or decreases, its motion energy has increased or decreased.

Sequence of Experiences		
1. Introduce the new unit	All Class	5 Minutes
2. Elicit students' ideas about energy	Discussion	20 Minutes
3. Investigate the motion energy of balls	Pairs	20 Minutes
4. Make meaning	Discussion	15 Minutes

Materials and Preparation

For the class:

- Large sheets of paper and markers
- Energy video montage and a means for showing it to the class
- A rubber ball (1¼ in. diameter)
- A wooden track and modeling clay to level it (the teacher can use one of the student tracks) – See Preparation

Materials for each pair of students

For each small group of 2 students:

- A set of 3 notecards with “No motion,” “Slow motion,” and “Fast motion”
- A rubber ball (1¼ in. diameter)
- A wooden track and modeling clay to level it

For each student:

- Motion Energy Student Notebook

Preparation:

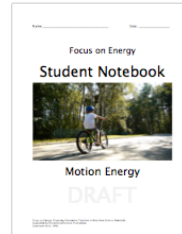
- Read *Motion Energy Curriculum Unit Overview.*
- Read *Scientific Models: An Introduction* and *What is an Energy Story?,* on the Focus on Energy website in Motion Energy -> Resource Quick Links.
- Watch the *Video Montage – Energy in Everyday Life* and review the accompanying page of stills. The video is available on the *Focus on Energy* website on the Curriculum -> Motion Energy -> Resource Quick Links page.
- Watch the *Motion 1: Setting Up and Using Equipment video* available on the *Focus on Energy* website on the Curriculum -> Motion Energy -> Resource Quick Links page.
- A level track is very important to the investigation. Prior to the start of class, set up the track on the floor or on a table, in a place where it will be clearly visible to all. Place a ball on the track and use modeling clay to make the track level. When the track is level, the ball will not roll no matter where it is placed along the track.

Motion 1: Setting Up and Using Equipment Video

1. Introduce the new unit

All class – 5 min

Explain that the class is about to start a new investigation, about *energy*. Everyone will have a science notebook. As they learn about energy, here's where they can write their ideas, record observations, make drawings, write predictions, ask questions…the notebook can be used in lots of different ways.



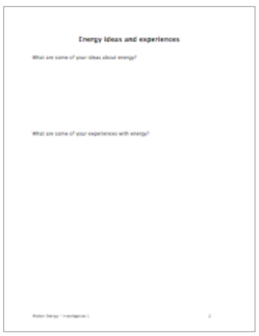
Distribute the Motion Energy Student Notebooks.

2. Elicit students' initial ideas about energy

Discussion – 20 min

Let's begin. I'm sure you are familiar with the word energy, and know some things about energy.

Ask students to take 2-3 minutes to write about their ideas about energy and/or experiences they have had with energy.



Notebook Page 2: *Energy ideas and experiences*

Take about two minutes to have a few students share one of the ideas about energy that they wrote in their Student Notebooks. Listen without making judgments.

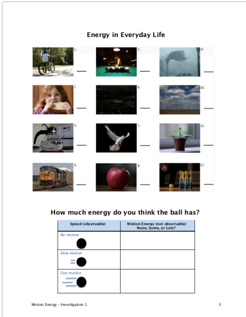
Video

Note: The video shows various forms of energy (motion energy; thermal energy; light energy) as well as energy *transfer* (e.g. from the bowling ball to the pins). The video is intended to elicit students' initial ideas about energy so you can build on them.

We're about to see a short video. It takes about a minute. As you watch, keep thinking about energy and pay close attention to what's going on.

Play the Video Montage. It is available under Curriculum -> Motion Energy -> Resource Quick Links on the *Focus on Energy* website.

Ask students to turn to Notebook Page – Motion 1, page 3: Energy in Everyday Life, which includes 12 "stills" taken from the energy video montage.



Notebook Page 3: *Energy in Everyday Life*

Explain that each picture represents one of the video clips they just watched.

> *I'll play the video again.*
> *As you watch each clip, put the letter "E" (for energy) next to any picture from any video clip that you think contains evidence of energy.*
> *Ask yourself, "What made me think that energy was present?"*

Show the video a second time, while students mark their sheets. Then, ask students to use their sheets to anchor a short discussion.

The purpose of this discussion is to elicit student ideas about energy prior to instruction. It is not a time to teach.

Discussion Question:

> *To which clips did you assign an "E?"*
> *What was the clue, or evidence, that caused you to think there was energy in this scenario?*
>> *Explain your thinking.*
>> *Does anyone want to add to that idea?*
>> *Is there anyone who did **not** think this clip should have an "E"? Would you explain why?*

Note: Students may comment on several different energy forms. This is fine. If students comment on factors that are not actually visible (e.g., "There is fuel inside the train to make it go, so that is energy.") ask them if there are any clues or indicators of energy that they <u>actually observed</u>. The motion of the train is an example of an indicator that it has energy.

Some common examples of students' ideas prior to instruction are: living things have energy; things that move have energy; an apple that isn't moving and isn't attached to a tree does not have energy; lights on the train or the city are evidence of energy; the bicycle and the train are moving so they get energy from somewhere.

Introduce Motion Energy

> *You found evidence of energy in [almost] every clip. You described lots of different kinds of evidence – motion, light, sound. Here's the challenge: **we can't see or feel energy** so we have to look for clues or evidence that it is present.*
>
> *Somebody mentioned that motion is a sign of energy. That's a good connection to today's investigation, which is to explore a kind or form of energy we call **motion energy**. If an object is moving, it has motion energy. For example, if a bike is moving, it has motion energy. We can talk about the motion energy of the bike.*

Note: We purposely introduce the expression "the motion energy *of* the bike." In this curriculum, students will learn to track the flow of energy; they will focus on where the energy is, where it is going, and what are the indicators of its presence. They will say the energy *of* the ball, or the ball's energy, and they will track where the ball's energy goes. On the other hand, if you use the words "the ball *uses* energy," that expression may take the focus off where the ball's energy is or even imply that the energy is used up or gone.

Introduce the investigation question

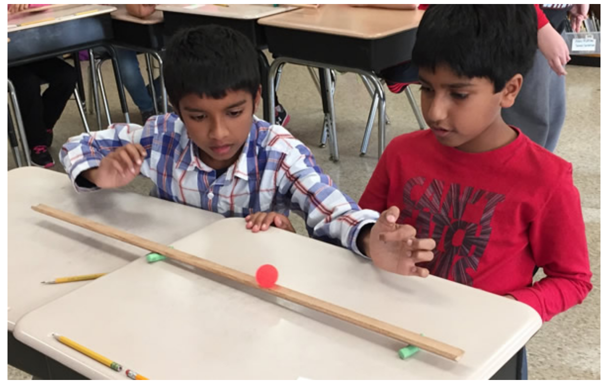
Our lessons always start with a question. Today's investigation question is:

What Can Motion Tell Us About Energy?

3. Investigate the motion energy of balls

Pairs – 20 min

A key idea for students to grasp is that energy can be present along a continuum of magnitudes: something can have the tiniest bit of energy, or a huge amount of energy, or any amount in between. It is not simply either present or not present. Having students roll a ball at different speeds, and later discuss how the ball can have different amounts of motion energy, helps build this idea.



Distribute Balls and Tracks

Give each pair of students a short piece of track, some modeling clay to level the track, and one ball, and ask them to explore rolling the ball along the level track, emphasizing that their pushes should be gentle enough to keep the ball on the track.

> **Note:** Students will need help with the concept of "level". Some will think that "flat" is the same as level. Use a counter example to start. Put a ball on a sloping surface and explain that the ball moved because the surface was not level. Then demonstrate how to put a small amount of modeling clay under one end of the track and manipulate it to make it level. When the ball does not roll, the track is level.

Distribute Motion Notecards

Give each pair a set of 3 motion notecards (see materials). Present the activity as a simple game. One member of each team holds the three cards, selects one to place face up on the table, and the other member responds by rolling the ball in a way that matches the description on the card: **no motion** (ball sits still); **slow motion** (gentle push); **fast motion** (bigger push). After each team member has a chance to play each role ask them to fill in the table on page 3 of their Notebook.

How much motion energy do you think the ball has as it rolls at different speeds? None, some, or lots?

Speed (observable)	**Motion Energy (not observable)** None, Some, or Lots?
No motion	
Slow motion	
Fast motion	

Have students come together in a discussion circle around your demonstration track and ball.

Link the speed of an object, which we can see, to amount of motion energy, which we cannot see.

You have all had a chance to roll the ball at different speeds: no motion, slow motion, and fast motion. What did you decide about the motion energy of the balls when they rolled at different speeds?

Ask students to observe the ball at rest.
One of the cards you used said No Motion. Tell me the energy story of that ball.
How did you decide?
Does everyone agree?
➔ A ball that is not moving has no motion energy.

Roll the ball slowly and ask for a description of the motion energy of the ball, and finally roll it quickly. Encourage students to describe *changes* in motion energy in terms of more motion energy or less motion energy.
You've just told three energy stories. But you can't see energy. How did you decide what the story is?

Note: For a given object, greater speed means more motion energy. Speed is an *indicator* of an object's motion energy. However, an object's speed is not the only factor in determining how much energy it has; an object's *mass* is also a factor. For two objects moving at the same speed, the one with greater mass will have more motion energy. This unit will not introduce the complicating factor of mass to students at this point in time.

4. Make meaning

Discussion – 15 min

The purpose of this discussion is for students to begin to generate a model of energy, based on their experiences.

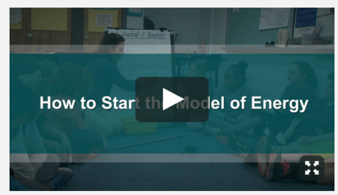
Return to the investigation question: What can motion tell us about energy?

Let students know that they will continue to explore motion energy in the next session. They will end today's session by having a conversation about what they have learned about energy today, and particularly about motion energy.

Start to Build a "Model of Energy"

We can't see energy, but based on our experiences today (watching video clips, observing a ball on a track) what can motion tell us about energy?

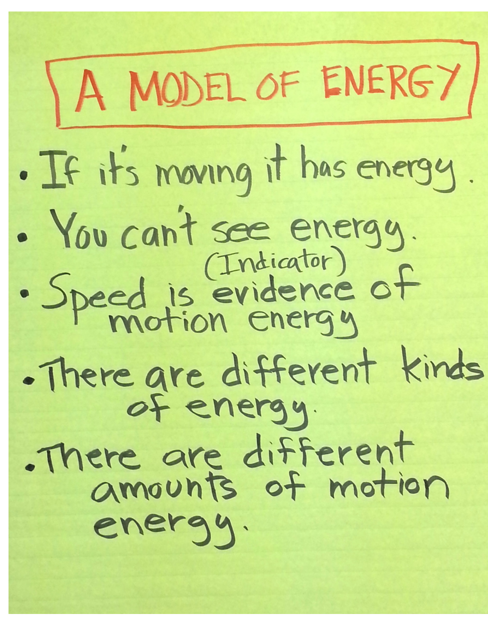
Watch a class start to build a model of energy.



How to Start the Model of Energy video available in Resource Quick Links on the Focus on Energy website

Record statements on chart paper, white board, or something similar titled A Model of Energy. You will continue to add to or refine this list in future sessions.

As they generate this list, the class is starting to generate a model of energy–using evidence to describe the nature and behavior of energy. Using and generating models is an important scientific practice.



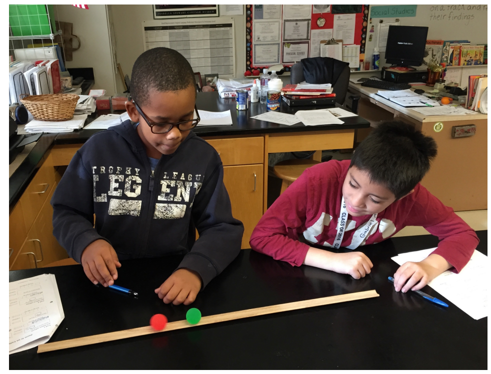
Possibilities include statements related to the video and/or to the balls. Listen for and record the key ideas of the Investigation, using student language.

Check to see if key ideas from the Learning Targets are being included:

- Energy cannot be directly seen or measured.
- All moving objects have motion energy.
- Speed is the indicator of how much motion energy an object has. If an object's speed increases or decreases, its motion energy has increased or decreased.

When a ball causes another ball to move, does it always lose some of its own energy?

Plan Investigation 2



This investigation introduces motion energy transfer. Students are introduced to energy bars as a way of representing 1) the amount of energy an object has and 2) the energy gains and losses when energy is transferred during a collision. The concept that energy is conserved is not addressed directly. However, the idea that, an energy gain in one place must be accompanied by an energy loss somewhere else is introduced and highlighted. These concepts set the stage for an introduction of the *Energy Tracking Lens* (See Part 2 below), which will emerge as a key tool for understanding energy. Students will become familiar with the *Energy Tracking Lens* as they move through the rest of the Motion Energy sequence.

In this investigation students are introduced to the concept of energy transfer as they explore collisions between small rubber balls on a track. They then observe collisions of balls on the classroom track when they address the investigation question: When a ball causes another ball to move, does it always lose some of its own energy?

Learning Targets Introduced in this Investigation

- Energy can move from one object to another object; this is called energy transfer.
- Motion energy can be transferred between objects through pushes, pulls, hits, or collisions.
- Stronger interactions (e.g., bigger hits) transfer more motion energy.
- Energy changes take place in multiples; whenever there is a loss of energy somewhere, there must be a gain in energy somewhere else (and vice versa).
- A drawing or representation (such as energy bars) can show changes in the amount of energy an object has.

Sequence of Experiences		
1. Introduction	All Class	5 Minutes
2. Explore Collisions	Pairs / All Class	15 Minutes
3. Collisions Investigation	All Class	15 Minutes
4. Make Meaning	All Class	15 Minutes
5. Quick Check	Individual	10 Minutes

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Materials and Preparation

For the class:

- A wooden track and modeling clay to level it
- 2 rubber balls (1¼ in. diameter, different colors)

For each small group of 2 students:

- A set of 3 notecards with “No motion,” “Slow motion,” and “Fast motion”
- A wooden track and modeling clay to level it
- 2 rubber balls (1¼ in. diameter, different colors)

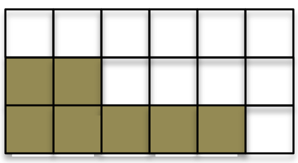
For each student:

- Motion Energy Student Notebook

Materials for each pair of students

Preparations:

- Set up and level the track on a table where students can gather around and observe.
- Make a large drawing of 3 energy bars on the white board or large piece of paper.



A: no energy – all squares empty

B: some energy – fill in 1 to 3 squares

C: lots of energy – fill in 4 to 6 squares

- Place the Model of Energy poster where all can see.
- Make preparations to show the short video *Quick Check: Block Push Probe* to the class after the Make Meaning discussion. The link to the video is on the *Focus on Energy* web site, under Curriculum Units -> Motion Energy -> Resource Quick Links.
- Read [What’s Important about the Energy Tracking Lens?]

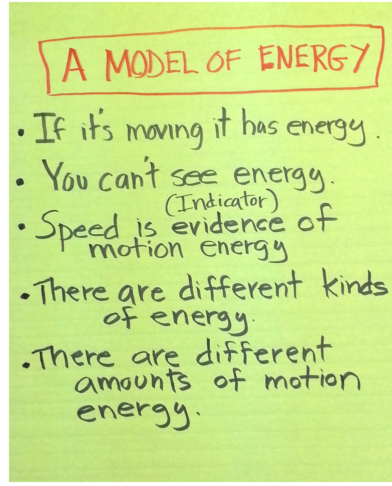
1. Introduction

All Class – 5 Mins

Start with a brief review of the Model of Energy that students developed during the previous class.

Explain the word **collision**: when objects crash into one another one we call it a "collision," or we say that they collide.

Explain that in this class students will observe and think about collisions and the idea that one ball can give energy to another ball as they collide. They will also think about how energy flows from one object to another; where the energy comes from and where it goes.



2. Collisions

Pairs/All Class – 15 mins

> **Note**: In the Student Notebook and this Teacher Guide, the ball that is moving prior to the collision is referred to as Ball #1. The ball that is NOT moving prior to the collision is referred to as Ball #2.

Demonstration

Gather students around the table with the demonstration track.

Place Ball #2 half way along the track.

Does this ball that is sitting on the track have motion energy?
➔No

What makes you think that?
➔It's not moving so it has no motion energy.

Can I use Ball #1 to give motion energy to Ball #2?

Roll Ball #1 toward Ball #2 at a moderate speed. After the collision, Ball #2 should be moving more quickly than Ball #1.

Did Ball #1 give energy to Ball #2? Explain why you think it did or did not.

Note: Ball #2 started with no motion energy (it was not moving) but after Ball#1 hit it, Ball #2 moved so it did have motion energy, and Ball #1 lost some motion energy (It slowed down). So, Ball #1 gave some of its motion energy to Ball #2.

How could I give Ball #2 even more energy?
➔Roll Ball #1 even faster.

Repeat the collision.

Scaffold students' ability to describe the collision in terms of motion energy. Reinforce the idea that changes in speed are what tell you about changes in motion energy.

> *Thinking about what you just observed, describe changes in the motion energy of **Ball #1**. Use the terms:*
> *• No motion energy*
> *• Some motion energy*
> *• Lots of motion energy*
>
> *Start by saying "before the collision …" and then "after the collision …"*
> ➔ Before the collision, Ball #1 had lots of motion energy. After the collision, Ball #1 first had some motion energy–although less than before the collision– and then it had no motion energy.
>
> *How did you decide that Ball #1 had lots of motion energy before the collision and no motion energy at the end?*
> ➔ Before the collision, the ball was moving fast so it had a lot of motion energy and after the collision, when it had stopped it didn't have any motion energy.
>
> *What about **Ball #2**?*
> ➔ Before the collision, Ball #2 had no motion energy. After the collision, Ball #2 had lots of motion energy.

Explore collisions in pairs

Have students return to their desks to work in pairs.

Give each pair of students:

- a piece of track
- some modeling clay to level the track
- two balls
- a set of 3 motion cards.

Remind students to level the track using modeling clay and give them 5 minutes to explore collisions, working in pairs. One student places cards, one at a time, on the table and the other rolls Ball #1 at different speeds (matching the description on the card) to cause a collision with Ball #2. After 2 minutes, have students switch roles.

> *Remember, we can't see energy so we're going to pay attention to the indicator, something we can see: changes in how fast or slow the ball is moving, which we call speed.*

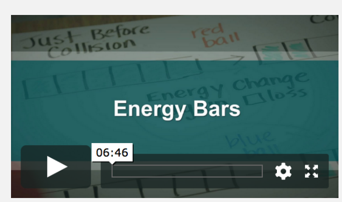
Collect the balls, tracks, cards, and modeling clay before moving on to the next part of the investigation.

Introduce "energy bars" representation

Share the following points:

- When scientists want to share their ideas with others, one thing they do is make drawings that show their ideas. Another term for these drawings is "representations".
- The cards you have been using, with the balls and *speed lines* for no motion, slow motion, and fast motion, are representations. They represent the speed at which the ball traveled.
- Today students will learn about a representation for energy, not speed.

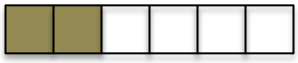
Watch a teacher introduce energy bars.

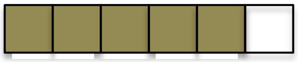


Energy Bars video available in Resource Quick Links on the Focus on Energy website

Refer to the large drawing of 3 energy bars on the white board or large piece of paper that you prepared ahead of time.


A: no energy – all squares empty


B: some energy – fill in 1 to 3 squares


C: lots of energy – fill in 4 to 6 squares

Use a ball to demonstrate the three options and ask students to say which energy bars to use (A, B, or C).

> *We are going to investigate energy changes that happen during a collision and you'll need to make lots of representations very quickly.*
> *• You can use speed lines to represent the motion of the balls.*
> *• You can use energy bars to represent the motion energy of the balls.*

3. Collisions Investigation

All class – 15 mins.

Students have watched several collisions by now.

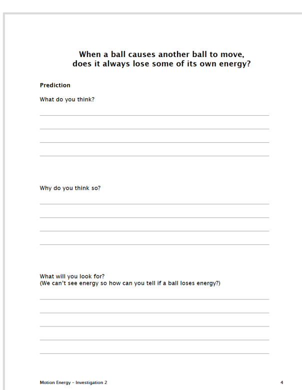
Introduce the investigation question:

When a ball causes another ball to move, does it always lose some of its own energy?

The way to answer this question is to collect some data (this is what students are about to do). You will use the balls to cause several collisions, and each time students will watch carefully and record in their Student Notebooks how much energy the balls have, before and after the collision. They will then fill in Energy Bars to represent the amounts of energy.

Predict

First, ask students to turn to page 4 in their science notebooks and take 2-3 minutes to write their predictions and explain their reasoning.


When a ball causes another ball to move, does it always lose some of its own energy?

Prediction

What do you think?

Why do you think so?

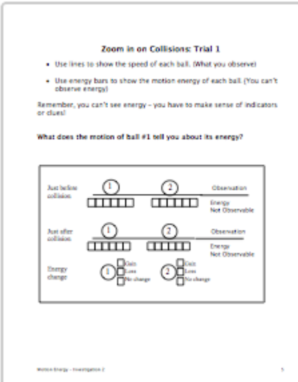
What will you look for?
(We can't see energy so how can you tell if a ball loses energy?)

Motion Energy – Investigation 2 4

Notebook Page 4: *When a ball causes another ball to move, does it always lose some of its own energy?*

Collect data

Have students bring their notebooks and pencils with them as they gather around the demonstration track. Ask students to turn to page 5 in their notebooks called *Zoom In on Collisions: Trial 1*.



Zoom in on Collisions: Trial 1

- Use lines to show the speed of each ball. (What you observe)
- Use energy bars to show the motion energy of each ball. (You can't observe energy)

Remember, you can't see energy – you have to make sense of indicators or clues!

What does the motion of ball #1 tell you about its energy?

Notebook Page 5,
Zoom in on Collisions: Trial 1

Do Trial #1 and practice using "speed lines" and energy bars.

Explain you are going to place Ball #2 on the track so it isn't moving and roll Ball #1 towards it but grab it shortly before the balls collide.

Ask students to use *speed lines* (similar to what was used on the cards) to describe the **motion** of both balls before the collision (point students to the "Just before collision" section at the top of the box on page 5.
Now describe the ***energy*** *of each ball –before the collision– by filling in the energy bars right underneath the images of the balls.*

Check that students understand the organization of the data sheet and how to use the speed lines and energy bars. When a ball is not moving, there are no speed lines and the energy bar should be empty. The energy bar for the moving ball should have 1-6 squares colored in depending on its speed.

Remind students of the distinction between the indicator (speed, which is visible) and motion energy (which is not visible).

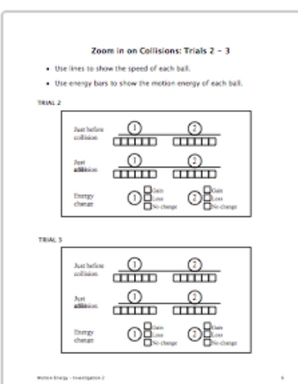
Now direct students to the "Just after collision" section in the middle of the box. Again, roll Ball #1 towards the stationary Ball #2, this time letting the balls collide. Have students complete both the observations and the energy bars.

Now have students describe the energy **change** for each ball – was there an energy gain, loss, or no change?

Repeat the investigation question

When a ball causes another ball to move, does it always lose some of its own energy?

Explain they have just finished one trial. Do students agree that the first ball lost some of its motion energy after the collision? Is what they found always true, or might it ever be possible for the first ball to **not** slow down, **not** lose motion energy?



Zoom in on Collisions: Trials 2 – 3

- Use lines to show the speed of each ball.
- Use energy bars to show the motion energy of each ball.

TRIAL 2

TRIAL 3

Complete Trials #2 and #3.
Tell the class you will now do two more trials. You will give them time after each trial to complete the speed lines (their observations) and the energy bars.

The main focus should be on Ball #1 immediately before and after the collision, since the investigation question is about Ball #1.

Notebook Page 6
Zoom in on Collisions: Trials 2 – 3

With everyone in the class watching closely, we'll try to find out if it is possible for Ball 1 to give some motion energy to Ball 2 AND to still keep the same amount of motion energy.
How would we know if Ball 1 keeps all of its motion energy?

➔ It would not slow down.


Can a ball cause another ball to move and NOT lose any energy?

What did you find out?

Does this make sense to you? Why or why not?

Think of an example from your everyday life where there's a loss of energy somewhere and a gain of energy somewhere else.
Describe your example.

After students have recorded the data for Trials #2 and #3, have them return to their desks and to use the evidence they have gathered from 3 trials to answer the questions on page 7 in the Student Notebook.

Notebook Page 7

When a ball causes another ball to move, does it always lose some of its own energy?

4. Make Meaning

All class – 15 mins

Have students bring their notebooks to the discussion circle so they can refer to their written responses and data.

The purpose of this discussion is to answer the investigation question.

Our investigation question today is:
When a ball causes another ball to move, does it always lose some of its own energy?

What did you predict?
Ask a few students to read their predictions from their notebooks. Be sure to give them time to explain the reasons behind their ideas.

*What actually happened? What did you **see**? Refer to your notebooks.*
➔ Every time Ball #1 hit Ball #2, it looked like Ball #1 slowed down and Ball #2 changed from no motion to slow motion or fast motion.

Did anyone see something different?

Consider the data from the whole class. It is unlikely that many students will have missed the reality that after a collision, the Ball #1 always slows down.

Now, what is the energy story? Today's question is actually about the energy, which we cannot see.
➔ When Ball #1 hits Ball #2, Ball #2 gains energy. I know that because it speeded up – it went from having no motion to having motion. Ball #1 slowed down in every trial and that's evidence it lost some of its energy.

Be sure that all students agree that Ball #1 lost energy.

Does anyone have a different idea about the energy story?

What do you think is the answer to our investigation question?

➔ When a ball causes another ball to move, it always loses some of its own energy.

Let's think about energy gains and losses: when one ball gains motion energy, the other ball always loses motion energy. Gains and losses seem to go together. Let's keep thinking about this as we explore energy in other ways.

Introduce the term *Transfer*

*There is a word that is used to describe what happens when energy moves from one object to another. That word is **"transfer."***

Write the word **transfer** in a place where all can see it.

When one object collides with another, and gives some of its motion energy to the other object, we say that motion energy is transferred from one object to the other object.
Would someone describe the energy story of a collision between Ball #1 and Ball #2 using the word "transfer?"

➔ Before the collision, Ball #1 has a lot of motion energy, but when it hits Ball #2, some of its motion energy transfers to Ball #2.

Add to the model of energy

There were several new ideas about energy that the class discussed today. Let's look at our Model of Energy. What do you think we can add, based on our experience today?

Ask for volunteers to make suggestions as you add to the Model of Energy.

Listen for and highlight these key ideas.

- The term *transfer* describes what happens when energy moves from one object to another.
- Motion energy can be transferred between objects through collisions.
- In a collision, one ball gives (or transfers) some of its energy to another ball.
- One ball has to have energy to give or transfer energy to another ball.
- Energy Bars are a way to describe or represent how much energy an object has.
- Whenever there is a loss of energy somewhere, there's a gain in energy somewhere else (and vice versa).

If students do not mention one or two of these key ideas, you may call it to their attention. For example,

"I observed everyone using energy bars. What can we say about energy bars?"

Explain that the class will continue to investigate energy in systems with different components…not just balls and tracks… and that all of these ideas will continue to be important.

5. Quick Check

Individual – 10 mins.

> If you are unable to show the 10 second video and have students complete the Quick Check before the science class ends, find another time to implement it and to read student responses prior to starting the next Investigation, since the results can help shape how you proceed.

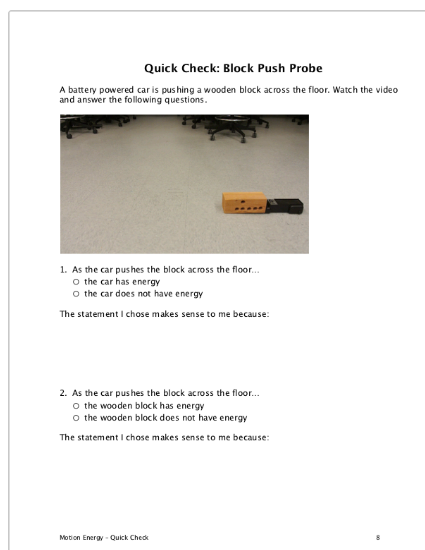
Block Push Probe

Show students the 10 second video *Quick Check: Block Push Probe* at least twice, and then ask them to turn to page 8 in their notebooks, read the *Block Push Probe* Scenario, and answer the questions.

This item will provide evidence of students' progress toward the learning goals for this investigation.

Students will need 5-10 minutes to complete the Quick Check. After you look at student results, plan time for students to discuss their responses.

The interpretation guide (available on the *Focus on Energy* website, under Curriculum Units -> Motion Energy -> Resource Quick Links -> Quick Check: Block Push Probe) will help you interpret student multiple choice answers and open-ended explanations.



Quick Check: Block Push Probe

A battery powered car is pushing a wooden block across the floor. Watch the video and answer the following questions.

1. As the car pushes the block across the floor...
   - ○ the car has energy
   - ○ the car does not have energy

The statement I chose makes sense to me because:

2. As the car pushes the block across the floor...
   - ○ the wooden block has energy
   - ○ the wooden block does not have energy

The statement I chose makes sense to me because:

Motion Energy – Quick Check 8

Notebook Page 8
Quick Check: Block Push Probe

Motion Energy – Investigation 3A

Can a paint paddle gain and lose energy?

Plan Investigation 3A

Today students start the first of three investigations that highlight elastic objects, elastic energy and energy transformation.

- An **elastic object** is an object that spontaneously returns to its original shape after it has been deformed (bent, twisted, stretched, compressed, etc.) Examples include springs, playground balls, and rubber bands.

- An elastic object that has been deformed (e.g., a compressed spring) has **elastic energy**. The amount of elastic energy is indicated by the amount of deformation. Elastic energy can also be described as "stored energy" or "potential energy." However, there are many forms of stored or potential energy, such as energy in food or energy in batteries. In this unit we use the term elastic energy to focus on this specific form of stored energy.

- **Energy transformation** refers to the process of energy changing from one form to another. For example, when that compressed spring is released, it moves! Its elastic energy is transformed into motion energy. If you watched a very slow motion video of a compressed spring after release, you would see that when it first starts to move, it is also still mostly compressed. Therefore, it has both motion and elastic energy at the same time. The transformation from elastic energy to motion energy happens over time, starting with 100% elastic, to a changing split percent between elastic and motion, to 100% motion energy when it is in its uncompressed shape.

Today's investigation focuses on the energy story of a bent paint stirrer or "paddle" and a pompom. When the bent paint paddle is released it propels a pompom into the air. The paint paddle is very much like a tiny diving board, except that it can be held in its deformed position by a latch and released at any time. If there is a pompom on the deflected paint paddle when the latch is released, some of the paint paddle's motion energy is transferred to the pompom. This transfer, and the transformation from elastic energy to motion energy, are the key ideas in this investigation.

The term "transformation" is not formally introduced until the Make Meaning portion of the class, after students have had some firsthand experience with the process.

Learning Targets Introduced in this Investigation

- An elastic object is any object that returns to its original shape after being deformed (bent, twisted, stretched, squeezed, etc.)
- Deformation of an elastic object is the indicator of the object's elastic energy. If an elastic object's deformation increases or decreases, its elastic energy has increased or decreased.
- When energy changes from one form to another, this is called energy transformation.
- Elastic energy can be transformed into motion energy (and vice versa).

Sequence of Experiences		
1.Review	All Class	10 Minutes
2. Introduction	All Class	15 Minutes
3. Explore	Pairs	15 Minutes
4. Make Meaning	All Class	15 Minutes
5. Wrap Up	All Class	5 Minutes

Materials and Preparation

Materials for each pair of students

For the class:

- 1 paint paddle (not connected to a base)
- 1 can insulator or holder

Provided by Classroom

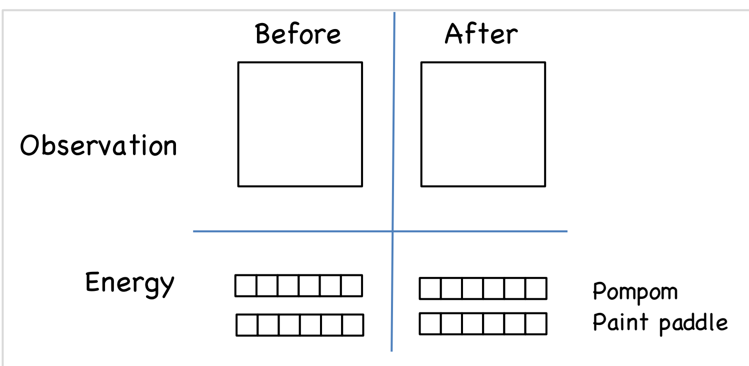
- 1 empty soft drink can
- A collection of elastic objects, e.g., rubber band or exercise band, spring, pop up or wind-up toy

For each group of 2 students:

- 1 "springboard"
- 1 pompom

Preparation

- Place the Model of Energy poster where all can see.
- On the class whiteboard or blackboard, make a simplified reproduction of pages 9 and 10 in the student notebook (see example). You will use this during the Make Meaning discussion.



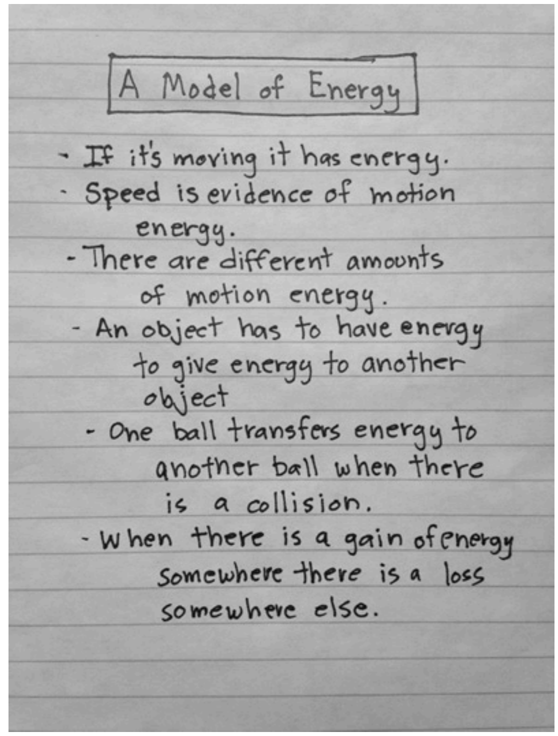
- Watch the *Motion 3A: Setting Up and Using Equipment video* available on the *Focus on Energy* website on the Curriculum -> Motion Energy -> Resource Quick Links page.
- Check to be sure the nut is tight on the paint paddle bolt. If the nut is loose it may be impossible for the paddle to be latched in the deflected position.

Motion 3A: Setting Up and Using Equipment Video

1. Review

All class – 10 Mins.

Refer to the class' growing list of statements about energy—the Energy Model—that they have developed over the course of investigations 1 and 2. Ask the students if there is anything here they would like to change or add.



There are two key ideas that may have been added to the classes' Energy Model by the end of the first two investigations.

1. An object has to have energy to give or transfer energy to another object.

2. Whenever there is a gain of energy somewhere, there's a loss somewhere else. (The converse is also true.)

If these ideas aren't on the list, add them now.

Ask students to say more about them or give an example of each one, most likely from Motion 2, involving collisions.

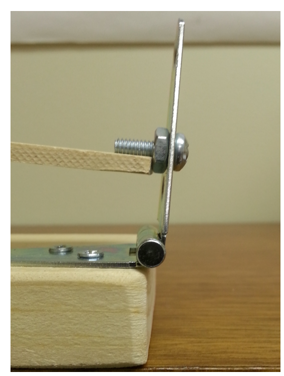
These two energy concepts will be very helpful as students try to understand where the energy came from to shoot the pompom into the air, and to introduce the concept of elastic energy.

2. Introduction

All Class – 15 Mins.

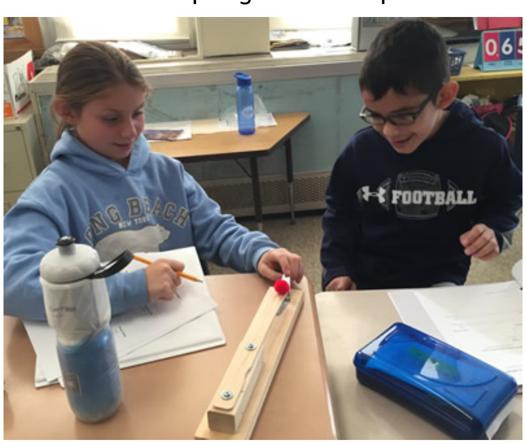
Today's question is:

"Can a paint paddle gain and lose energy?"



Show students a paint paddle (paint stirrer) and ask if anyone knows what it is used for. Some will be unfamiliar with it.

Introduce the springboard and point out the paint paddle. Demonstrate how to lock the paint paddle in the bent (deformed) position using the latch and just the threaded part of the bolt (see photo), not including the nut. Place a pompom on the paint paddle. Then, release the latch, sending the pompom into the air.



Distribute springboards and pompoms to pairs of students.

Explain that students have about 2 or 3 minutes to explore this new system and that everyone needs to try it. Students should use the latch–not their fingers–to hold the paint paddle in its bent position as they investigate the new system.

Elicit students' ideas

Bend and latch the paint paddle again and place a pompom on its end.

Do you think that the paint paddle has energy now?

At this point, students may say yes. They may say no, it's not moving. Make sure they explain their reasoning.

Release the latch, sending the pompom flying into the air.

Do you think that the pompom has gained energy when it's flying in the air?

How can you tell?

➔ Yes, before it was still and now it's moving

Whenever something gains energy, something else loses energy. If the pompom gained energy, what do you think lost energy?

Students may say the paint paddle, the latch, or your hand.

Tell them that today they will be investigating the energy story of the paint paddle. At this point, just acknowledge responses without confirming or correcting.

> **Note**: It is common for students to bring up the concept of *force* at various points during these investigations. A focus on forces is a common way to analyze a system. And a focus on energy is another way to analyze that same system. We have heard students claim that the latch that holds the paddle in its deflected position has "energy." In this case, the latch (with attached bolt) is just exerting a force on the paddle to hold it in its deflected position. There is no "latch energy".

Introduce the concept of elastic objects.

Show the class the empty soft drink can wrapped in an insulated holder.

Many objects, when they are deformed…squeezed, or bent, or twisted, or stretched…will stay that way. They will not return to their original shape by themselves.

Remove the empty can from the holder, crush it in your hand or step on it, and show the class the crushed can.

Will this return to its "can shape" by itself?

Some objects, when they are deformed…squeezed, bent, twisted, stretched…WILL return to their original shape by themselves.

Show the class the insulated can holder, squeeze it, and then release it.

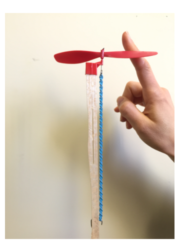
These objects that return to their original shape by themselves are called ***elastic*** *objects.*

Can you think of other elastic objects (not materials) that will return to their original shape after they have been deformed…squeezed, twisted, bent, stretched?

➔ Playground balls, basketballs, pillows made of foam rubber, rubber bands, bicycle tires, springs, sponges, etc.

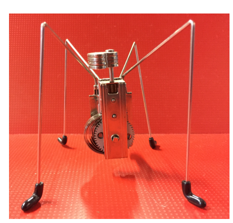
Have a variety of elastic objects on hand that you can use to demonstrate.

Stretch



Twist

Bend



Squeeze (compress)

Hold up the springboard with the paint paddle in the bent and latched position.

Do you think that the paint paddle is an elastic object?

➔ It returns to its original shape by itself, so I think that it is an elastic object.

Introduce elastic energy

*Remember we have been investigating **motion energy**. Today we are exploring another kind or form of energy called **elastic energy**. When an elastic object is stretched, squeezed, twisted, or bent, it has elastic energy.*

Remind students that the pompom gained motion energy as it changed from being still to flying through the air. Since it gained energy, something else (the bent paint paddle) had to lose energy. The latched paint paddle wasn't moving so its energy must be a new form. The new form is called elastic energy. It was the paint paddle's elastic energy that was lost as the pompom gained energy.

3. Explore

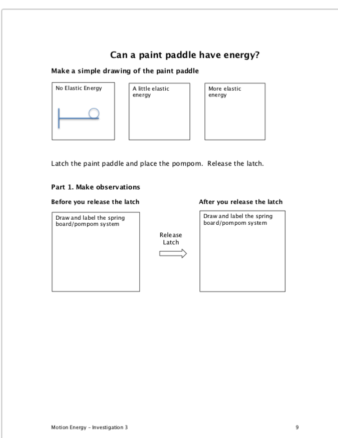
Pairs – 15 Mins.

Remind students that they have been learning to look for evidence or indicators of motion energy, and have told the energy story of collisions. Explain that today they have a new energy story to figure out. The story includes the energy of the springboard and the energy of the pompom.

Explain that students have about 2 or 3 minutes to continue exploring this system.

Explore bending the paint paddle down just a little bit, a little bit more, and bending it all the way down. What happens to the pompom in each case? What does that tell you about energy?

Ask students to turn to page 9 of their notebooks and compete both page 9 and page 10. Provide about 5 or 6 minutes for students to make their notebook entries.


Can a paint paddle have energy?

Make a simple drawing of the paint paddle

No Elastic Energy | A little elastic energy | More elastic energy

Latch the paint paddle and place the pompom. Release the latch.

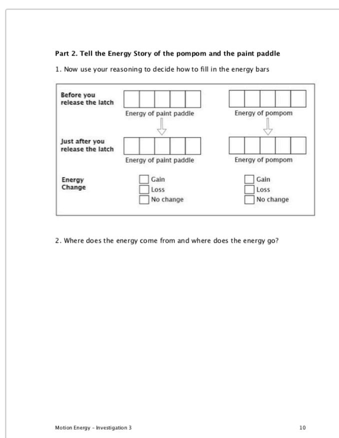
Part 1. Make observations

Before you release the latch — Draw and label the spring board/pompom system

Release Latch

After you release the latch — Draw and label the spring board/pompom system

Motion Energy – Investigation 3 9


Part 2. Tell the Energy Story of the pompom and the paint paddle

1. Now use your reasoning to decide how to fill in the energy bars

Before you release the latch	Energy of paint paddle	Energy of pompom
Just after you release the latch	Energy of paint paddle	Energy of pompom
Energy Change	Gain / Loss / No change	Gain / Loss / No change

2. Where does the energy come from and where does the energy go?

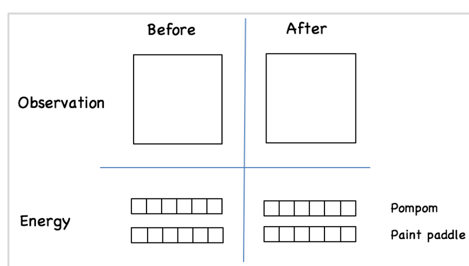
Motion Energy – Investigation 3 10

Notebook pages 9 and 10
Can a paint paddle have energy?

4. Make Meaning

All Class – 15 Mins.

The purpose of this discussion is to develop –as a class– an energy story of the springboard and the pompom. Ask students to bring their notebooks as they form a discussion circle close to the whiteboard or blackboard with the simplified reproduction of pages 9 and 10.



Ask representatives from different groups to first share their observations. Ask volunteers to fill in the Before and After observations in the boxes previously drawn on the board.

Let's start with what you actually observed that helped you tell the energy story.

Next ask students to use their observations to develop an energy story. Remind them that they cannot see energy; they can only see the indicators or clues. Ask them to discuss not only their energy bars but also what they have written on page 10. Responses relating to energy gains and losses, motion energy, elastic energy, and where the energy comes from and where the energy goes—the transfer of energy from the paint paddle to the pompom—are all key ideas they should be able to articulate.

You cannot know ahead of time exactly how the discussion will unfold. Some groups may get to the idea of transformation of elastic to motion energy in the paint paddle right away; others may begin with gains, losses or transfer of energy from the paddle to the pompom. Below you will find suggestions of questions that address evidence, gains and losses, indicators of amounts of elastic energy and transformations.

Fill in the energy bars on the board according to class consensus.

What evidence can you use for changes in the elastic energy of the paint paddle?

➔ The more we bent the paint paddle the higher the pompom flew, so the more it was bent the more elastic energy it had.

Indicators are clues that tell you about different amounts of energy.

The indicator for how much motion energy a rolling ball has is its speed. Can you think of an indicator that would tell you about the amount of energy in the springboard? Explain your thinking.

➔ The indicator for how much elastic energy the paint paddle has is how bent it is – when it's straight, it has no elastic energy. The more it's bent, the more elastic energy it has.

Where do you think the paint paddle's energy came from and where does the energy go?

➔ As I bend the paint paddle, I give it energy. My body loses energy, and the paint paddle gains energy. Because the paint paddle is an **elastic object**, it gains **elastic energy**. When I release the paint paddle, it loses elastic energy and gains motion energy as it returns to its original shape. The paint paddle gives some of its motion energy to the pompom. The pompom gains motion energy.

Introduce the term "energy transformation"

Demonstrate bending the paint paddle and holding it down with your hand.

In this bent shape, the paint paddle has elastic energy. When I let go, what kind of energy does the paint paddle have?

➔ Motion energy

Bend and then release the paint paddle a few more times, naming the type of energy each time: …elastic energy…motion energy…elastic energy …motion energy.

So that's another new idea: <u>one form of energy can change into another form of energy</u>. Elastic energy of the paint paddle can change form, or transform, into motion energy of the paint paddle.
*We call this **energy transformation**. The word transformation means change of form.*

5. Wrap Up: Add to the Energy Model

All Class – 5 Mins.

Return to the Energy Model that students have been developing during the previous class periods.

What can our exploration of elastic objects tell us about energy?

They should be able to add these ideas, in their own words:

1) Objects that automatically return to their original shape after being deformed are called elastic objects.

2) Elastic objects that are deformed have a kind of energy we call elastic energy.

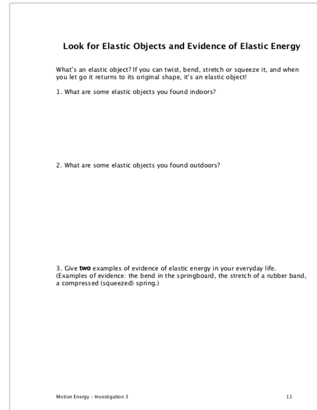
3) If an elastic object changes its shape more, its elastic energy increases.

4) Energy can change or transform from one form to another, for example, from elastic energy to motion energy.

In the next class you will use many of the ideas you have explored today, including elastic objects, elastic energy, energy transfer, and energy transformation, to look more closely at the energy story of the paint paddle.

Look for Evidence of Elastic Energy

You may want to ask students to look for examples of elastic objects and elastic energy in their everyday life and answer the questions on page 11 of the student notebook. If you have time, have students share their findings and thus broaden everyone's understanding of elastic objects and energy. You can also have students complete this page as homework.


Look for Elastic Objects and Evidence of Elastic Energy

What's an elastic object? If you can twist, bend, stretch or squeeze it, and when you let go it returns to its original shape, it's an elastic object!

1. What are some elastic objects you found indoors?

2. What are some elastic objects you found outdoors?

3. Give **two** examples of evidence of elastic energy in your everyday life. (Examples of evidence: the bend in the springboard, the stretch of a rubber band, a compressed (squeezed) spring.)

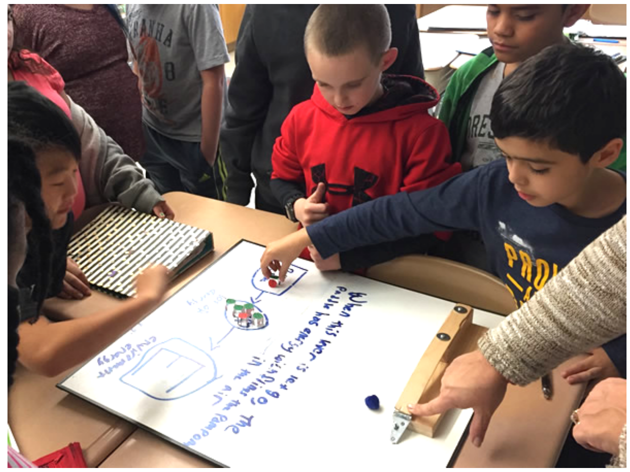
Motion Energy – Investigation 3 11

Motion Notebook, page 11
Look for Elastic Objects and Evidence of Elastic Energy

Motion Energy – Investigation 3B

What's the energy story of the paint paddle and the pompom?

Plan Investigation 3B



Today students continue their investigation of motion energy, elastic energy and energy transformation. Students are introduced to energy cubes (see *Energy Cubes Rules* at the end of this investigation) and they then use the cubes to reason about the energy story of the springboard. Energy cubes are an effective tool for representing both the transfer of energy between objects and the *transformation* of energy from one form to another.

In the case of the paint stirrer, elastic energy is transformed into motion energy and vice versa. As the hand pushes down on the tip of the paint paddle, the person transfers energy to the springboard. As the board is deformed, motion energy is transformed into elastic energy. As the springboard is released and returns to its original shape, its elastic energy is transformed into motion energy. Some of that motion energy is transferred to the pompom, and it soars into the air. Some students may notice that the springboard vibrates a bit before becoming motionless. Some of your students may want to use cubes to reason about energy transformations in the vibrating board. You will need to use your judgment about whether or not to engage the whole class in this analysis; the energy of the springboard goes through a rapid series of transformations, back and forth between elastic energy and motion energy.

What do students think about the pompom's energy once it hits the ground and is no longer moving? While the full energy story can be very complex, for now it is sufficient for students to claim that the pompom's motion energy was transferred to the environment.

Learning Targets Introduced in this Investigation

- Energy cubes can be used to reason about energy flows and forms.

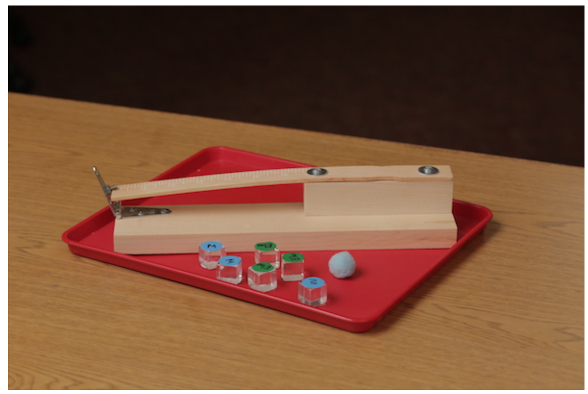
Sequence of Experiences		
1. Introduction	All Class	20 Minutes
2. Answer the Investigation Question	Discussion / Pairs	20 Minutes
3. Make Meaning	All Class	20 Minutes
4. Optional: Energy story of diving board?	All Class	

Materials and Preparation

For the class:

- Colored round stickers for labeling the Energy Cubes
- 6 classroom-size (large) Energy Cubes labeled M for Motion Energy on one face and Elas for Elastic Energy on another face.
- A large sheet of paper *
- A colored marker *
- A wooden track and plasticine to level it
- 2 rubber balls (1¼ in. diameter, different colors)
- Optional: Video of a person diving (on the *Focus on Energy* website, in Curriculum Units -> Motion Energy -> Resource Quick Links)
  https://focusonenergy.terc.edu/curriculum/motion/diving_video.html

* A section of whiteboard and erasable markers can substitute for the paper and colored markers.



Materials for each pair of students

For each group of 2 students:

- One "springboard" with pompom
- 6 student-size (small) Energy Cubes labeled M for Motion Energy on one face and Elas for Elastic Energy on another face
- A large sheet of paper and colored markers or a white board and dry erase markers

Preparation:

- Prepare a set of six classroom-sized energy cubes. On each cube, attach one color label on one face, and a second color on another face. Use a fine-tip marker to write M for Motion Energy on one label and Elas for Elastic Energy on the other.

- Prepare a set of six student-size energy cubes for **each pair** of students. Label cubes with an M for Motion Energy on one face and Elas for Elastic Energy on another face.
- Read *An Introduction to Energy Cubes* (includes the Energy Cube Rules) on the *Focus on Energy* website in Motion Energy -> Resource Quick Links.
- Read *Using Sketches to Document Energy Cube Movement* located at the end of this investigation.
- Post the Model of Energy and Energy Cube Rules where all can see them.

1. Introduction

All class – 20 Mins.

If you assigned the *Look for Elastic Objects* homework to your students (See Investigation 3A) you may want to hear about their discoveries before you start this investigation.

> **Note:** Energy cubes and circles provide a powerful option for representing the way energy flows and transforms as it moves through a system. However, energy flow is a dynamic process; it changes from one moment to the next. Therefore, this representation requires that the user always be aware of the moment in time that she/he is representing when using the cubes. In demonstrating the use of energy cubes, be sure your narration highlights the **time** aspect as you move the cubes.

Ask students to gather around a large sheet of paper. Have a colored marker and 6 labeled energy cubes.
Have a demonstration wooden track and 2 balls and a springboard and pompom on hand.

> Watch a teacher introduce energy cubes.
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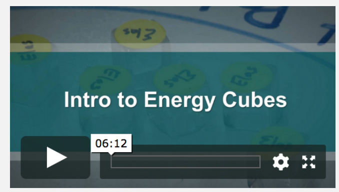
> 
>
>
> Intro to Energy Cubes video available in Resource Quick Links on the Focus on Energy website

You have used sketches, words and energy bars to tell the energy story of colliding balls and of the springboard launching the pompom. Today we learn about another way to tell the energy story, using energy cubes. The cubes will help us think about and explain the flow of energy in a system.

Tell students that you will introduce energy cubes to tell a familiar energy story: a collision between a moving ball and a stationary ball.

Draw and label two circles, one for Ball #1 and one for Ball #2. Put the name of the object in each circle.

Explain that each circle represents an important *component* of the system.

Introduce the energy cubes and discuss the Energy Cube Rules with the class. Highlight these points:

- Each energy cube represents a unit of energy.
- Energy cubes are an excellent way to represent two important energy ideas: energy *transfer* and energy *transformation* as energy moves through a system.
- Slide a cube from one circle to another to show energy transfer (demonstrate).
- Rotate (flip) a cube from one face to another to show energy changing from one form to another – energy transformation (demonstrate). Highlight the practice of flipping the cube at the location where the transformation occurs.
- The total number of energy cubes (usually 6) must always remain the same. Students can add new circles to move the cubes to, but can't add or take away any cubes.

Engage students in using the cubes to tell the energy story (See *Energy Cube Rules*, below). Place Ball #2 half way along the track. Roll Ball #1 toward stationary Ball #2. Stop Ball #1 before the collision.

When Ball #1 was moving, before the collision, where should we put the energy cubes? Where was all of the motion energy of this system just before the collision? Explain your answer.

➔ A student puts all 6 cubes in the Ball #1 circle, with "M" up, since Ball #1 is moving and has motion energy. The Ball #2 circle remains empty. It is not yet moving and so has no motion energy.

> **Note:** Slide the cubes from one circle to another. This sliding motion is important. It highlights the fact that the same unit of energy can **transfer** from one place to another.

Roll Ball #1 again, this time letting the two balls collide.

Just after the collision, when Ball #1 has hit Ball #2 and Ball #2 has started to move, what should I do with the cubes?
➔ A student moves four or five cubes to the Ball #2 circle keeping the M side up to show that Ball #2 has gained motion energy. Ball #1 is still moving a bit, so 1 or 2 cubes cube remain in the Ball #1 circle. Emphasize that the exact way the cubes are distributed will depend on the reasoning of the person using the cubes to tell the energy story.

Repeat that the cubes show motion energy of the two balls just a moment after the collision.

Should I turn the cube over to show that there is elastic energy in this collision scenario? [no]

Let students know that they will be using Energy Cubes and circles as they reason together about the energy story of the paint paddle and the pompom. If they have any questions about the Energy Cubes they can ask now.

2. Answer the Investigation Question

Discussion/Pairs – 20 Mins.

Still in the discussion circle, turn to the investigation question,

"What's the energy story of the paint paddle and pompom?"

Explain that students will use energy cubes and circles to tell the energy story of the paint paddle and pompom. Everyone will begin the story when the paint paddle is bent and latched, and the pompom is sitting on top of it. (Show a springboard and pompom in this position.)

- Ask students what circles you should draw and label for this scenario [one for the paint paddle and one for the pompom]. Put the name of the object in each circle.

Refer to the bent and latched paint paddle with a pompom on it.

Before I release the latch, where should we put the energy cubes? Explain your answer.
➔ Put all 6 in the paint paddle circle, with "Elas" up. Nothing is moving and the paint paddle is bent so it has elastic energy.

To reinforce the relationship between Elastic Energy and its indicator—deformation of an object away from its natural shape—hold the paint paddle in position with your finger so it does not move when you release the latch. Let the paddle rise about one third of the way to horizontal and ask:

How many Elastic Energy cubes would you leave in the paint paddle circle now?
➔ Students should suggest removing 1 or 2 cubes.

Allow the paddle to rise another third of the way up and repeat the question. Then let the paddle come to its undeformed (horizontal) shape and repeat the question. In its undeformed shape the paddle would have no elastic energy.

Remind students that they can turn over the cubes, leaving the "M" side facing up, to show motion energy.

Mention that as students start to work with their own sets of cubes, they should refer to the Model of Energy they have been developing during the first three classes and is posted on the classroom wall.

Introduce the Energy Tracking Lens

Have students open their Student Notebooks to page 1, **The Energy Tracking Lens**. Some of the questions should already look familiar. Tell students that, from now on, they should refer to the Energy Tracking Lens and think about each question each time they tell an energy story.

The Energy Tracking Lens

Part 1. Describe what you observe.

Part 2. Tell the energy story.

- System components?
- Form(s) of energy?
- Energy gains and losses?
- Energy transfers?
- Energy transformations?
- Where does the energy come from and where does the energy go?

Use observations to support your energy story.

Distribute materials

Give each pair of students a large sheet of paper (or whiteboard), colored markers, labeled energy cubes, a springboard, and a pompom. Tell them to use circles and the energy cubes to tell the story about the flow of energy through the springboard and pompom system.

Explain after about 5 minutes they will be asked to share their energy cube stories with the class.

3. Make Meaning

All Class – 20 Mins.

The purpose of this discussion is to share energy stories with classmates, listen to ideas of others and become familiar with the energy cubes as a tool for telling an energy story, including transfers and transformations. At the end of the discussion, you will introduce Energy Flow Diagrams as another way to tell an energy story.

Gather students in a circle and have different groups use cubes and circles to tell their version of the springboard energy story. They should "narrate" the energy story as they move or flip the cubes, explaining their reasoning and describing the evidence that leads them to the decisions they make. Are they addressing the key ideas? Do they

- identify the components of the system?
- talk about the different forms of energy?
- use the terms transfer and transformation as they move or flip the cubes?
- flip the cubes in the correct place to show where the energy transformation occurs?
- describe energy gains and energy losses as energy moves through the system?
- describe where the energy comes from? Where it goes?

Ask students to add on to the energy story. Have the paint paddle and pompom on hand so they can observe additional details.

Some students may notice that the paint paddle is still moving after the pompom is in the air and suggest keeping one or more cubes in the paint paddle circle with the M side up, and moving fewer cubes to the pompom with the M side up.

Some students may notice that as the springboard loses elastic energy, it gains motion energy and suggest that there be both "Elas" cubes and "M" cubes in the springboard circle. They have evidence to support the idea that an object may have two (or more) forms of energy at the same time.

Introduce Energy Flow Diagrams

Make one or two sketches of a consensus energy story, representing a few moments in time, to make a record of the energy story the students developed using cubes. (See *Using Sketches to Document Energy Cube Movement*) Highlight the fact that the number of cubes remains the same: energy does not just disappear or appear from nowhere. Put an "M" or an "Elas" on the face of the cubes. In the next investigation, students will be asked to make their own sketches of an energy story that uses energy cubes.

> **Note**: The drawings in *Using Sketches to Document Energy Cube Movement* provide simplified representations of a complex energy story but represent perfectly good examples of representation as viewed by a student at this point. They address energy form, energy transfer, energy transformation when appropriate, and energy conservation. They also address (within limits) where the energy came from and where it went.

Add to the Model of Energy

Students should be able to add, in their own words, that energy cubes can be used to reason about energy transfers and transformations.

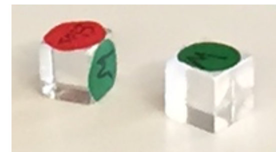
4. Optional: What's the energy story of the diving board?

All Class

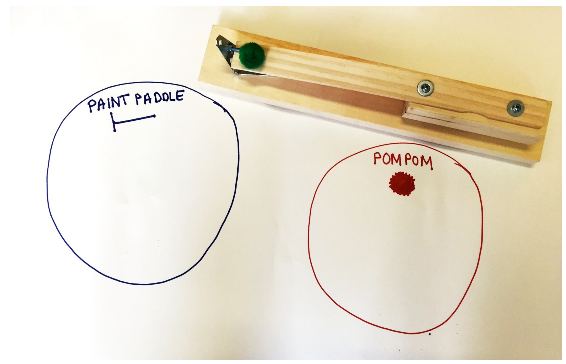
If you have time, you may ask the students to watch the video of a diver and use energy cubes to tell the energy story.

Show the Diving Video available on the *Focus on Energy* website in the Curriculum -> Motion Energy -> Resource Quick Links.

ENERGY CUBE RULES



- Each cube represents an equal-sized unit of energy.



- Circles on a white board or paper represent physical objects that are key components of the system being investigated

- The number of cubes in a circle corresponds to the quantity of energy of the component.

- Each cube indicates its form of energy with a symbol (such as "M" for motion energy) on the side facing up.

- To show energy transformation, flip cubes so that a different symbol (such as "Elas" for elastic energy) faces up.

- The number of cubes showing a particular symbol on the upward side corresponds to the quantity of a particular form.

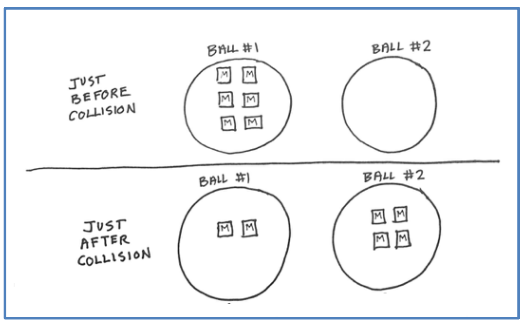
- To show energy transfer, slide cubes from one circle to another.

USING SKETCHES TO DOCUMENT ENERGY CUBE MOVEMENT

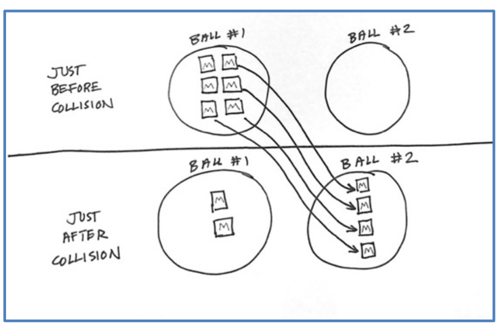
Energy flow through a system is a dynamic process, changing from moment to moment across time and space. Likewise, sliding and flipping the energy cubes through a set of component circles is a dynamic process and a very effective way to represent energy flow through a system. The cubes and circles help students to reason about energy flow and allow them to share their thinking with others involved in the work.

However, the cubes themselves provide no lasting record of student work. This means that students do not have the opportunity to return to a proposal to reconsider it, and teachers have no record of student work to review. A sketch or a photo of the cubes and circles can depict a moment in time but neither is an effective way to capture a dynamic process. The Focus on Energy curriculum therefore suggests that students create a series of sketches that document the location of energy cubes at two or more key points in time, possibly before and after an event, or before, during, and after an event. Below are just three of the many possible approaches to such sketches.

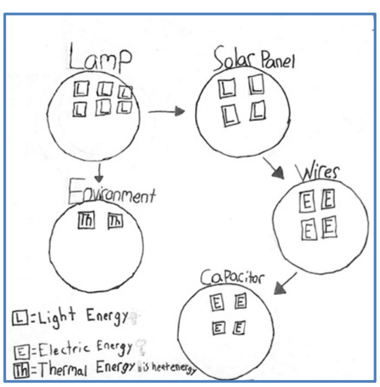
While these sketches are helpful to both the students who developed them and their teachers, they are not meant to inform those who were not involved in the work. They typically do not provide adequate information to be useful for that purpose.



Example #1: This sketch shows the motion energy of two balls immediately before and immediately after Ball #1 collides with stationary Ball #2.



Example #2: This sketch shows the same event of balls colliding as well as the same result in Example #1, but uses arrows to highlights the fact that most of the motion energy of Ball #1 was transferred to Ball #2 during the collision.

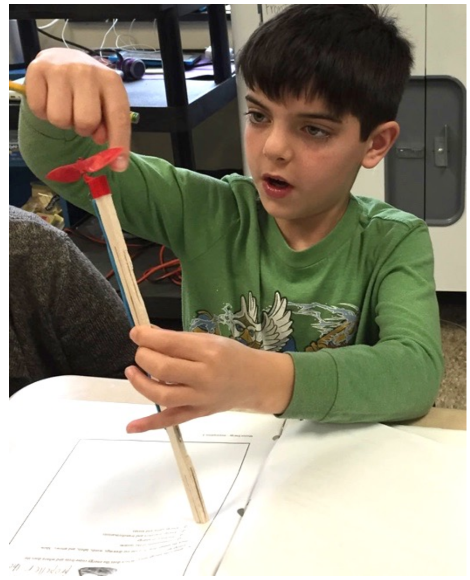


Example #3: This sketch uses a different type of representation. Arrows (vs a horizontal line) represent the passage of time as a “batch” of energy, represented by the cubes, moves through the system. Energy starts in the lamp, moves simultaneously to the solar panel and other parts of the environment, then through wires and into the capacitor.

Motion Energy – Investigation 4

What's the energy story of the propeller?

A model airplane propeller attached to an elastic band is the system that students analyze with the Energy Tracking Lens. Students work with Energy Cubes to reason about transfer and transformation in this system and raise the question of where the energy goes after the elastic band unwinds and the propeller stops moving.



A focus of this investigation continues to be on asking where does the energy come from and where does the energy go to "tell the energy story." Students consolidate their learning about the use of energy bars and energy cubes to represent the flow of energy in a system.

Learning Targets Introduced in this Investigation

- The Energy Tracking Lens questions, "Where does the energy come from?" and "Where does the energy go?" provide a useful way of thinking about energy flow in any scenario.
- Drawings and representations help students reason about energy flow and transformation in a scenario.

Sequence of Experiences		
1. Introduction – Link to previous sessions	All Class	10 Minutes
2. Introduce the Question	All Class	10 Minutes
3. Explore the propeller and elastic band	Pairs	20 Minutes
4. Make Meaning	Discussion	20 Minutes
5. Wrap Up Probe	Individual	

Supported by the National Science Foundation

Materials and Preparation

For the class:

- A large sheet of paper, approximately 18” x 24” or larger
- A felt tip pen
- 1 propeller-tube set-up (See Preparation)
- 1 springboard
- 1 pompom
- Set of 6 energy cubes

For each small group of 2:

- 1 propeller-elastic band system

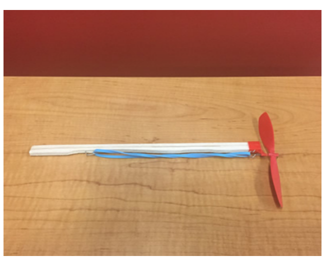
For each small group of 4:

- White board or large sheet of paper
- Markers
- Set of 6 energy cubes

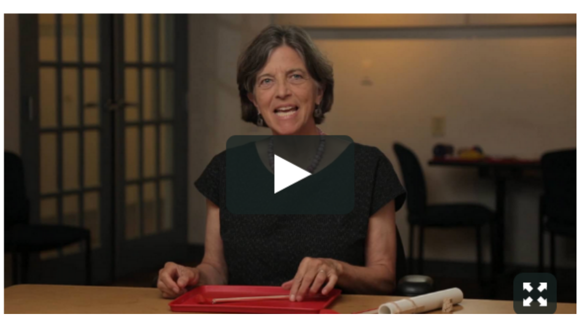

Materials for each group of students

Preparation:

- Propeller-elastic band system. See photos below. Attach the propeller and elastic band to the balsa sticks.
- Propeller-tube system: Insert a propeller-elastic band system into the tube. Push a cork into the end of the tube as shown in the image below, to press the balsa stick against the inside wall of the tube. This should be a snug enough fit to hold the balsa stick in place and prevent the cork from being accidently knocked out, yet not be so tight to make it difficult to remove the cork. The elastic band should remain hidden. Add the popsicle stick and the elastic bands, which act as a braking system. Prior to class, wind the propeller (25-30 rotations is adequate) and set the brake. The source of the energy should remain a mystery for students during the initial class demonstration.



- Watch the *Motion 4: Setting Up and Using Equipment video* available on the *Focus on Energy* website on the Curriculum -> Motion Energy -> Resource Quick Links page.


Motion 4: Setting Up and Using Equipment Video

- Be prepared to show the Unit Wrap Up video, *Giant Paint Paddle* (normal speed and slow motion), available in Motion Energy -> Resource Quick Links on the *Focus on Energy* website.

1. Introduction – Link to previous class sessions

All class – 10 Mins.

Review the following four points from previous classes:

1. In the first 2 classes we looked carefully at **motion energy**

2. In Motion-3A, we looked at another kind of energy**, elastic energy.**

   - An elastic object can change its shape by stretching, bending, twisting, squeezing and then go back to its original shape on its own (spontaneously). Examples: springboard, elastic band.
   - Indicators of amount of elastic energy (amount the springboard is bent, amount the rubber band is stretched).
   - Elastic energy can be **transformed** into motion energy.

3. We learned to use Energy Cubes to tell the energy story of a pompom being flung into the air by a springboard.

4. Whether it's colliding balls or flying pompoms, we keep asking the same questions. Remember, we call this the Energy Tracking Lens:

   Part 1. Describe what you observe.
   Part 2. Tell the energy story.
   System components?
   Form(s) of energy?
   Energy gains and losses?
   Energy transfers?
   Energy transformations?
   Where does the energy come from and where does the energy go?

(The questions are listed at the front of the science notebook.)

Today we're going to look at another scenario that involves both motion and elastic energy.

The Energy Tracking Lens

Part 1. Describe what you observe.

Part 2. Tell the energy story.

- System components?
- Form(s) of energy?
- Energy gains and losses?
- Energy transfers?
- Energy transformations?
- Where does the energy come from and where does the energy go?

Use observations to support your energy story.

2. Introduce the Question

All class – 10 Mins.

Today's question is:

What's the energy story of the propeller?

Show propeller in a tube.
Are there indicators of energy? [no motion, no stretching]

Slide the brake (popsicle stick) down, allowing the propeller to spin and then quickly raise it before the propeller stops spinning. Ask for observations.
What happened? Are there indicators of energy?
➔ The propeller moved, which indicates it gained motion energy.

If the propeller gained energy, where did the energy come from? If a gain in one place means a loss in another, what lost energy?

Collect ideas about what's in the tube [battery, twisted rubber band]. Remove tube and reveal propeller/elastic band system.)

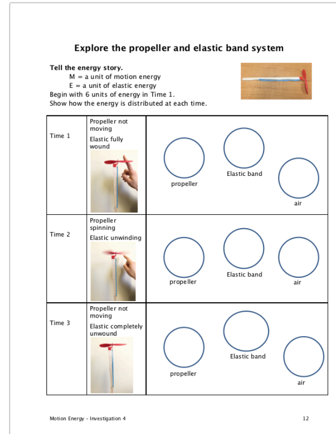
3. Explore the propeller and elastic band system

Pairs – 20 Mins.

Direct students' attention to Notebook p.12, *Explore the propeller and elastic band system*. Highlight directions that are on the notebook page.

> *Your challenge is to make observations and to describe the energy of the red propeller and elastic band. Begin when the elastic is wound, and the propeller is not moving. Release the propeller and end when the elastic is completely unwound and the propeller is not moving.*

Explain that they have about 15 minutes to explore what happens and to complete the notebook page.



Explore the propeller and elastic band system

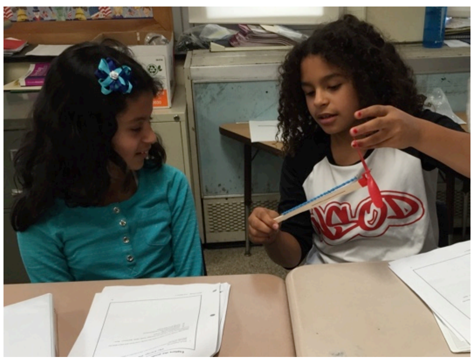
Tell the energy story.
M = a unit of motion energy
E = a unit of elastic energy
Begin with 6 units of energy in Time 1.
Show how the energy is distributed at each time.

Time 1	Propeller not moving Elastic fully wound	propeller · Elastic band · air
Time 2	Propeller spinning Elastic unwinding	propeller · Elastic band · air
Time 3	Propeller not moving Elastic completely unwound	propeller · Elastic band · air

Motion Energy – Investigation 4 12

Notebook p.12

Distribute Materials



Give a propeller and elastic band systems to pairs of students.

Warning: *Please don't turn the propeller more than 25 times – We have found that the rubber band can break when twisted more than that.*

Optional: Give energy cubes, a white board or large piece of paper, and markers to groups of four students. This gives them an opportunity to use cubes to share ideas about the energy story and better prepare themselves for the group discussion.

Collect the materials before gathering in a circle for discussion and Energy Cubes.

Learn more about small group learning in *Focus on Energy* lessons.

Small Group Learning video available in Resource Quick Links on the Focus on Energy website

4. Make Meaning

Discussion – 20 Mins.

Form a discussion circle. Ask students to bring their notebooks, open to page 11.

The purpose of this discussion is to use evidence and reasoning to tell the energy story of the rubber band and propeller system and to use Energy Cubes to represent energy flow.

Place a large sheet of paper and a set of energy cubes in the center of the discussion circle.

Hold up a propeller/twisted elastic system.

- Make circles to show the components of the system (propeller, rubber band).

Ask students to use the cubes to tell the energy story, paying particular attention to showing where the energy is at:

- Time 1: When the propeller is not moving, and the elastic band is twisted
- Time 2: When the propeller is spinning and the elastic band is unwinding
- Time 3: When there is no more motion in the propeller or the elastic band

Remind students to check the Energy Tracking Lens as they tell the energy story.

Listen to students' ideas. (The energy cubes move from the rubber band to the propeller, the energy cubes are turned over to show transformation from elastic energy to motion energy.)

Wind and release the propeller again so that students can look for additional evidence. As the elastic unwinds, students may notice that there is both motion energy and stored elastic energy in the same object at the same time.

Ask students for ideas about what happens to the cubes after all motion stops.

- Cubes move out of (transfer from) the propeller circle somewhere else (another circle: "air," "the environment," etc.)

This is a good opportunity to introduce air as part of the system. Students may have felt the air moving. The propeller transferred motion energy to the air.

Optional: The movement of air can be highlighted by asking students what happens when the propeller is turned counterclockwise vs clockwise. What is different? (Air flow changes direction.) This can lead later on to more questions about air being part of the system.

> **Note**: What happened to the energy once the air stopped moving? This is a complex topic but it may come up. First, it's hard to tell when the air stopped moving because it spread out, so more particles of air may just be moving much more slowly. Also, the motion of air eventually transforms into thermal energy, warming the air a tiny, imperceptible amount. A way to acknowledge that the energy did not just disappear is to have another circle for "the environment", which is a way of saying, "We don't know exactly what happened to the energy but we know it went somewhere. It did not simply 'go away'."

Point out that when the cubes were moved from one component to another, this is called **energy transfer**. When the cubes were flipped from one for to another – Elas to M (elastic to motion energy), this is called **energy transformation.**

Ask students to remember the colliding balls.

Was there energy transfer?

➔ yes, from one ball to another

Was there transformation?

➔ no, it was motion energy to motion energy

What about the springboard and pompom?

➔ yes, transfer from the springboard to the pompom and transformation of elastic energy to motion energy of the springboard

Did the springboard or pompom have two forms of energy at the same time?

➔ yes, the springboard had elastic energy and motion energy as it moved back to the unbent position once it was released.

Add to the Model of Energy

What should we add?

➔ Motion energy can be transformed into elastic energy (twisting the rubber band) and vice versa (itself unwinding and spinning propeller)

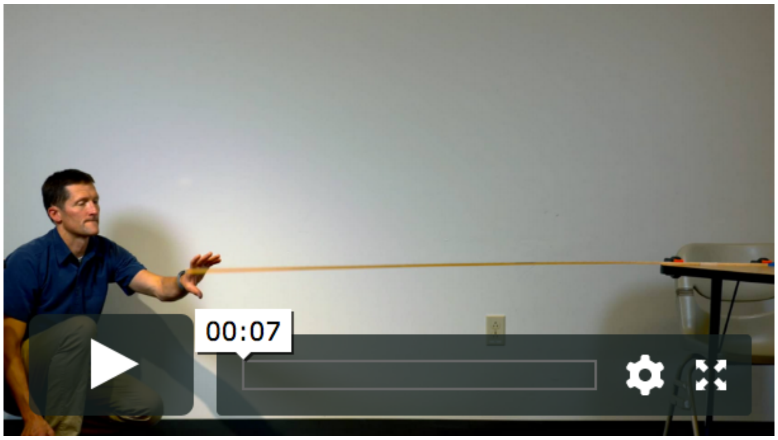
Time permitting, return to the introductory Video Montage. In the video clips, what does motion tell us about energy?

5. Wrap Up Probe

Individual

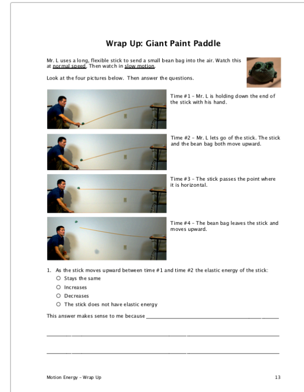
If you don't have time to implement the Unit Wrap Up Probe during this class period, find time to administer the probe prior to starting the next Unit:

- Ask students to turn to page 13 in the Student Notebook.
- Show students the short videos of the *Giant Paint Paddle*, first the normal speed version and then the slow motion version. Read the first question aloud and check that students understand the question. Show the videos one more time. Read the other questions aloud.



The link to the videos is on the Motion Energy Curriculum Resource Quick Links page.

- Allow 5-10 minutes for students to write their responses to the questions.



Wrap Up: Giant Paint Paddle

Mr. L uses a long, flexible stick to send a small bean bag into the air. Watch this at normal speed. Then watch in slow motion.

Look at the four pictures below. Then answer the questions.

Time #1 – Mr. L is holding down the end of the stick with his hand.

Time #2 – Mr. L lets go of the stick. The stick and the bean bag both move upward.

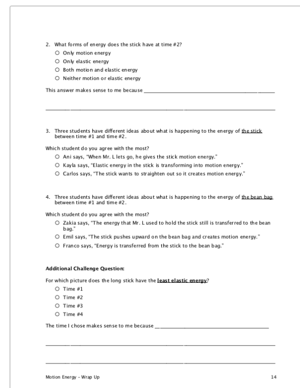
Time #3 – The stick passes the point where it is horizontal.

Time #4 – The bean bag leaves the stick and moves upward.

1. As the stick moves upward between time #1 and time #2 the elastic energy of the stick:
   - Stays the same
   - Increases
   - Decreases
   - The stick does not have elastic energy

This answer makes sense to me because ______

Motion Energy – Wrap Up 13



2. What forms of energy does the stick have at time #2?
   - Only motion energy
   - Only elastic energy
   - Both motion and elastic energy
   - Neither motion or elastic energy

This answer makes sense to me because ______

3. Three students have different ideas about what is happening to the energy of the stick between time #1 and time #2.

Which student do you agree with the most?
   - Ani says, "When Mr. L lets go, he gives the stick motion energy."
   - Kayla says, "Elastic energy in the stick is transforming into motion energy."
   - Carlos says, "The stick wants to straighten out so it creates motion energy."

4. Three students have different ideas about what is happening to the energy of the bean bag between time #1 and time #2.

Which student do you agree with the most?
   - Zakia says, "The energy that Mr. L used to hold the stick still is transferred to the bean bag."
   - Emil says, "The stick pushes upward on the bean bag and creates motion energy."
   - Franco says, "Energy is transferred from the stick to the bean bag."

Additional Challenge Question:

For which picture does the long stick have the **least elastic energy**?
   - Time #1
   - Time #2
   - Time #3
   - Time #4

The time I chose makes sense to me because ______

Motion Energy – Wrap Up 14

Notebook, p. 13 and 14

Wrap Up Probes are formative assessments. As such they are opportunities for both students and teacher to reflect on their learning. Plan time for students to discuss their responses to the probe, raise questions and clarify any area of confusion.

You might choose to collect students' notebooks before this discussion and project Wrap Up probe questions to guide the discussion. Or, you might have students keep their notebooks so they can refer to their responses during the discussion. At the conclusion of the discussion, you might provide time for students to revise their responses if they wish.

The interpretation guide (on the *Focus on Energy* website, in Curriculum Units -> Motion Energy -> Resource Quick Links) will help you interpret student multiple choice answers and open-ended explanations.