Oops!

4.2

Image via iStock.com/eternalcreative

Anchoring Phenomenon

A Rube Goldberg® machine stalls.

Lesson Concept

Ask questions about the contact forces and energy used to cause chain reaction.

Investigative Phenomenon

A Rube Goldberg® machine stalls when the paper roll doesn't knock over the glass.

Standards

Refer to Appendix 4.2 for NGSS, CCSS (ELA), and California ELD standards.

Storyline Link

In Lesson 1: What's Going On?, students identified cause and effect relationships in a chain reaction and analyzed a tool (mousetrap) against criteria. Students drew models of the cause and effect relationship using forces (and tentatively added energy as they understood it).

In this lesson, students investigate a Rube Goldberg® machine (chain reaction) that stalls. Students compare and contrast the sections of the system that work and those that don't in terms of force, energy (as they understand it), collisions, and speed. They look for cause and effect relationships and patterns in the data.

Throughout the unit, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

135 minutes

Part I

30 minutes Engage

Part II

45 minutes Explore

Part III

45 minutes Explain

Part IV

15 minutes Elaborate/Evaluate

Materials

Whole Class

- ❑ *Tom and Jerry* video (https://www.youtube.com/watch?v=GvnEBX9aedY&feature=youtu.be)
- ❑ *Audri's Rube Goldberg Monster Trap* video (https://www.waimeaelementary.org/apps/video/watch.jsp?v=111342)
- ❑ 4.2.R1: Rube Goldberg® Cartoon
- ❑ 4.2.C1: Energy Questions

Groups (Groups of 4)

- ❑ Sentence strips
- ❑ Chart paper (or large whiteboards)
- ❑ Markers

Individual

- Science notebook

Advance Preparation

1. Gather supplies.
2. Make sure the **Our Questions** chart and the **Our Thinking So Far** chart from Lesson 1: What's Going On? are available.
3. Make a chart from **4.2.C1: Energy Questions**. Note: This chart will be used in this lesson and the next lessons.
4. Preview the *Audri's Rube Goldberg Monster Trap* video.

Procedure

Part I

Engage (30 minutes)

Ask questions about the cause and effect relationships in a chain reaction that fails.

1. As a class, review the questions from the **Our Questions** chart from Lesson 1: What's Going On? Look for questions such as: *Do things like this happen in real life? Does it always work?* Explain that today students will have an opportunity to try to answer their questions.
2. Display **4.2.R1: Rube Goldberg® Cartoon** (How to Get Rid of a Mouse). Explain that while the students have just watched a cartoon, people actually do design machines that solve a simple problem in a complex way. These are called Rube Goldberg® machines, named after a man with a good sense of humor! Rube Goldberg (1883–1970) was a Pulitzer-Prize-winning cartoonist best known for his zany invention cartoons. He was born in San Francisco, graduated from the University of California, Berkeley with a degree in engineering, and went on to become a cartoonist who drew more than 50,000 cartoons. Each of his cartoons told a story, and his goal was to get readers to laugh. A Rube Goldberg® machine is "a comically involved, complicated invention, laboriously contrived to perform a simple operation."
3. Point to a question on the **Our Questions** chart that asks if Rube Goldberg® machines work in real life. Have students review their models from Lesson 1: What's Going On? What patterns did they notice? Chart their ideas. *Expected Student Responses (ESRs): Cause and effect forces caused objects to move and change direction, etc.* Discuss how these patterns might play out in a real Rube Goldberg® machine.
4. Say, "Here is a real Rube Goldberg® machine," and then play the *Audri's Rube Goldberg Monster Trap* video from the beginning to 1:38. Ask students to turn to a partner and discuss what they heard about how the Rube Goldberg® machine was going to work. Play *Audri's Rube Goldberg Monster Trap* video again, and ask students to record the sequence they think is supposed to happen in their science notebook, using cause and effect statements.
5. With a partner, ask students to compare their cause and effect statements about this Rube Goldberg® machine and some of the patterns they noticed in the **4.2.R1: Rube Goldberg® Cartoon** (Step 2). Conduct a class discussion about the patterns they expect to observe to make sure all students have a general idea of the planned actions.
6. Play the *Audri's Rube Goldberg Monster Trap* video from 2:18–2:23 (failure #2) and ask students just to observe. Play the section again. In table groups, ask students to discuss why the Rube Goldberg® machine stalled. What questions do they have?
7. Ask table groups to share their questions and wonderings and chart their responses on the **Our Questions** chart. *ESRs: Why didn't the ball push the tube to make the wine glass fall? How much force is needed to make the ball hit the tube to make the wine glass fall? The balls were bouncing around when they hit the paper roll—did that slow them so they didn't have enough strength/force/energy to hit the tube? What happened to the energy when the ball hit the tube? Why did it work from the beginning but didn't work for the paper roll section?*

A project of CA NGSS K–8 Early Implementation Initiative.

Part II

Explore (45 minutes)

Compare and contrast observations of the system a successful and failed Rube Goldberg® machine in terms of cause and effect relationships.

8. Look on the chart for questions such as "Why did it work in some places and not in others?" Discuss with students their ideas for comparing and contrasting the patterns of when the monster trap worked and when it did not.

9. To observe when it works, play the *Audri's Rube Goldberg Monster Trap* video (success) from 2:37–3:15) and ask students to just observe. Then replay *Audri's Rube Goldberg Monster Trap* and ask students to record observations in their science notebook.

10. Ask students how they might compare what they observed when the Rube Goldberg® machine worked versus when it stalled. If necessary, suggest that they do what they did in Lesson 1: What's Going On? Have them use sentence strips and models to compare different sections of the Rube Goldberg® machine.

TEACHER NOTE

Steps 11–14 are designed to build interdependence in the classroom. Half the room will create cause and effect statements for the successful Rube Goldberg® machine; the other half of the room will create a cause and effect statement for the failed Rube Goldberg® machine. Then groups will compare their sentence strips. The strips should be very similar to each other up to the point of the paper roll hitting the swivel tube. In the failed Rube Goldberg® machine, the sequence ends here. In the successful Rube Goldberg® machine, the sequence continues to the wine glass, release of the ball, and the cap being lowered onto the monster.

This side-by-side comparison should elicit student conversation about what is missing in the failed Rube Goldberg® machine compared to the successful Rube Goldberg® machine. Students may talk about this as force or strength, and hopefully energy. (See Step 16.)

11. Ask students what they mean by the word section, and then ask whether these sections could be considered systems. In groups, discuss whether they think sections match their understanding of what a system is (based on prior knowledge). Have groups share their ideas and come up with a class definition of what a system is. *ESRs: A group of related parts that make up the whole; the whole does more than the individual parts can do; if there is a change in a part, it can impact the whole.*

TEACHER NOTE

The 3–5 grade band of the K–12 progression for the crosscutting concept of systems and system models states, "Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot." Using prior Knowledge related to Systems and System Models from the K–2 grade band, students understand that objects and organisms can be described in terms of their parts and that systems in the natural and designed world have parts that work together.

In fourth grade, Systems and System Models is the focus Crosscutting Concept for Life Science where students learn, "A system can be described in terms of its components and their interactions." If you are teaching this learning sequence prior to a life science sequence, be sure to refer to this learning sequence so students can build on their understanding of system interactions when exploring systems in other science domains. In this way they will see that the crosscutting concepts really do help in making meaning across all science domains. If students have already experienced a life science learning sequence and have explored interactions in systems from a life science context, be sure to make explicit connections to that learning.

12. Ask partners to discuss why looking at a system might help them understand why the Rube Goldberg® machine worked in some parts but not as a whole. *ESRs: It might help us think about what happens in one part and how that affects the next part; it might help us observe what works in one part and why it doesn't work in another part.*

13. Divide the class into two groups: one group will look at the system that allowed the Rube Goldberg® machine to be successful; the other group will look at the system that failed. Distribute sentence strips and markers to groups. Ask students to select or be assigned a part of the system (make sure all parts are covered for both groups).

14. Ask students to write their cause and effect statements that explain the sequence on the sentence strips.

    - *ESRs for the successful Rube Goldberg® machine: Dominoes collided with each other causing the bowling pin to fall; the falling bowling pin pushes the gyroscope which hits the marker causing it to release the marble; the marble travels down the ramp and hits the switch causing the toaster to turn on. When the toaster is hot enough, it causes the lever to rise, "dumping" the ball that was in the tube; this ball collides with the other two balls to hit the paper roll, causing it to fall down and roll to the swivel tube. The swivel tube moves to knock down the wine glass with the steel ball; when it falls, it pulls on the pulley to lower the "cap," which falls on the monster and traps it.*
    - *ESRs for the failed Rube Goldberg® machine: Dominoes collided with each other causing the bowling pin to fall; the falling bowling pin pushes the gyroscope which hits the marker causing it to release the marble; the marble travels down the ramp and hits the switch causing the toaster to turn on. When the toaster is hot enough, it causes the lever to rise, "dumping" the ball that was in the tube; this ball collides with the other two balls which hit the paper roll, causing it to fall down and roll to the swivel tube and stop.*

15. Conduct a parallel sharing of the sentence strips at the front of the room using a class T-chart. Ask the successful group to share their first strip; then ask the failed group to share their first strip. (They should be similar.) Continue alternating for each step. After the step where the paper roll falls and hits the swivel tube, the failed group should be out of sentence strips, but the successful group continues to the end.

16. Debrief with the class what they noticed about the patterns in both situations. Ask the class to come to some consensus cause and effect statements about what they observed. *ESRs: There was not enough force/energy/speed at the end, but enough all the rest of the times; it needed something to stop the bigger balls from bouncing around; the collisions before helped things move along (dominoes to bowling pin to gyroscope to marker with small marble), but collisions of the big balls didn't hit the paper hard enough to get the force/energy to the tube.*

Part III

Explain (45 minutes)

Construct a model to explain the cause and effect action and the movement of energy in a Rube Goldberg® machine system.

17. Ask students what they might do to better understand how the action unfolded. Hopefully they will suggest drawing a model as they did in Lesson 1: What's Going On? If not, ask what they did to better understand the *Tom and Jerry* video.

18. Before having students create their models, return to the discussions about energy. Point to the sentence strips where the boy pushes the dominoes.

    - Ask questions such as, "What started the movement?" *ESR: The boy pushed it.* "How did the boy get the motion to push it?" *ESR: He moved his arm.* "What caused him to move his arm?" *ESR: He used his muscles.* "What do you need to move your muscles?" *ESR: Energy*
    - Scientists use the word energy whenever there is motion. Ask, "Do you think there was energy in the Rube Goldberg® machine?" *ESR: yes.* "How do you know?" *ESR: There was motion from the boy to the dominoes, and then the dominoes moved, etc.*

> **TEACHER NOTE**
>
> In this lesson, it is still okay for students to be struggling with how energy works in relationship to the contact force.

19. Provide chart paper and markers to the "part groups" to create a model just like they did in Lesson 1: What's Going On? to show how this machine operates. Ask what they might include in their model this time: *ESR: Parts of the model, labels, something that shows the motion, where is the energy.*

20. Allow groups time to work on their model, and then by table group, show the prompt on **4.2.C1: Energy Questions**: Where did the energy come from? What did it do? Where did it go? Have students consider these questions as they develop their model.

21. Select several table groups to share their models. Ask the class to compare these models to theirs. Identify what is similar and what is not similar in the models.

22. Ask students to think about what questions they have about the Rube Goldberg® machine. What are they wondering about? What else do they want to know? Chart questions on the **Our Questions** chart. *ESRs: What do we need to do to make the failed one work? Can I make it go faster? Can I get more energy into the Rube Goldberg® machine?*

Part IV

Elaborate/Evaluate (15 minutes)

Communicate information about how we know energy is present and that it moves from place to place in predictable patterns.

23. Focus on the **Our Thinking So Far** chart from Lesson 1: What's Going On? and add to or refine their thinking.

24. ▶ Tell students they are going to have an opportunity to apply what they learned in this lesson to Lesson 1: What's Going On? They will re-watch a clip of the *Tom and Jerry* video and identify observable changes in the system that provides evidence that energy is present. Provide students with the exit slip prompts: How do we know energy transferred in the system? Where does the energy come from? Where does the energy go? Then replay *Tom and Jerry* video (0:39–0:50).

25. ▶ Ask students to use words and/or pictures to answer the prompts. *ESR: The glove/hand transfers energy to the red pail each time it touches it. We know energy is transferred because we see the pail move. Then the sand falls from the pail and transfers energy to the blue pail. The blue pail is on the balance. When it fills with sand, the balance moves and hits the switch (applies a contact force), which transfers energy to the fan. The fan turns on, and the blades move, which creates wind. The wind transfers energy to the sailboat, and the sailboat and pool stick move across the pool. The pool stick hits the ball, and the contact force transfers energy, causing the ball to roll.)*

26. ▶ Collect exit slips.

TEACHER NOTE

▶ Review the exit slips to determine if students understood the targeted three dimensions of the lesson or if they need additional support or review in Lesson 3: Collisions and Speed.

References

Rube Goldberg. (2012, March 10). How to Get Rid of a Mouse! Retrieved from https://www.rubegoldberg.com/artwork/how-to-get-rid-of-a-mouse-2/.

TNTuxedoBlog. (2012, March 10). *Tom and Jerry - Rube Goldberg Fail*. Retrieved from https://www.youtube.com/watch?v=GvnEBX9aedY&feature=youtu.be.

Waimea Elementary School. (2016, April 25). *Audri's Rube Goldberg Monster Trap*. Retrieved from https://www.waimeaelementary.org/apps/video/watch.jsp?v=111342.

Toolbox Table of Contents

Energy Questions

1. What is the system of interest?

2. What are the parts of the system?

3. What observable changes are taking place in the system?

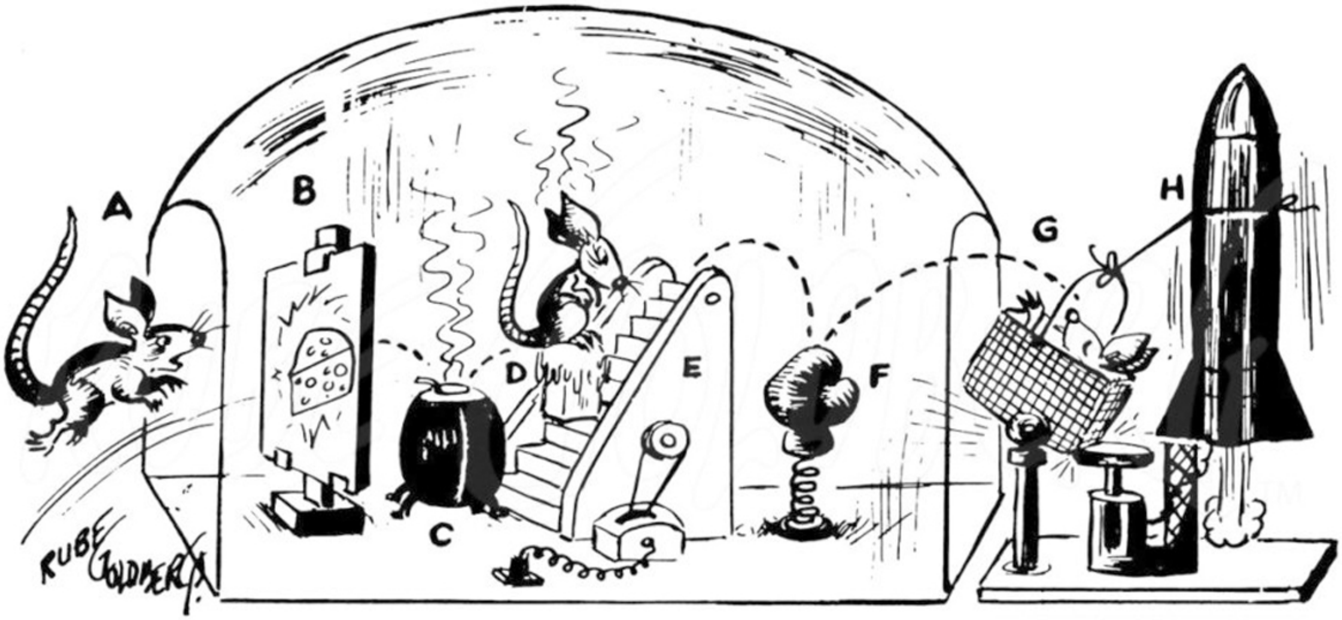
4. How is the energy transferred:
   - Where does the energy come from?

   - What does the energy do?

   - Where does the energy go?

Rube Goldberg® Cartoon

How to Get Rid of a Mouse



The best mousetrap by Rube Goldberg: Mouse (A) dives for painting of cheese (B), goes through canvas and lands on hot stove (C). He jumps on cake of ice (D) to cool off. Moving escalator (E) drops him on boxing glove (F) which knocks him into basket (G) setting off miniature rocket (H) which takes him to the moon.

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
4-PS3-1	Use evidence to construct an explanation relating the speed of an object to the energy of that object. *[Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]*
4-PS3-2	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. *[Assessment Boundary: Assessment does not include quantitative measurements of energy.]*
4-PS3-3	Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] *[Assessment Boundary: Assessment does not include quantitative measurements of energy.]*
4-PS3-4	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] *[Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]*

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Asking Questions and Defining Problems
• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
Developing and Using Models
• Develop and/or use models to describe and/or predict phenomena.
Analyzing and Interpreting Data
• Represent data in ~~tables and/or~~ various graphical displays ~~(bar graphs, pictographs, and/or pie charts)~~ to reveal patterns that indicate relationships.

Appendix 4.2

DISCIPLINARY CORE IDEAS (DCI)
PS3.A Definitions of Energy
• Energy can be moved from place to place by moving objects ~~or through sound, light, or electrical currents~~.
PS3.B Conservation of Energy and Energy Transfer
• Energy is present whenever there are moving objects, sound, light or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion.
PS3.C Relationships Between Energy and Forces
• When objects collide, the contact forces transfer energy so as to change the objects' motion.

CROSSCUTTING CONCEPTS (CCC)
Cause and Effect
• Cause and effect relationships are routinely identified, tested, and used to explain change.
Patterns
• Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena and designed products.
Systems and System Models
• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can also describe in terms of its components and their interactions.
Energy and Matter
• Energy can be transferred in various ways and between objects.

Common Core State Standards (CCSS)

CCSS ELA WRITING
CCSS.ELA-LITERACY.W.4.2
Write informative/explanatory text to examine a topic and convey ideas and information clearly.

Appendix 4.2

California English Language Development (ELD) Standards

CA ELD		
Part 1.4.1 Exchanging information and ideas with others through oral collaborative conversations on a range of social and academic topics		
EMERGING	EXPANDING	BRIDGING
Contribute to conversations and express ideas by asking and answering *yes-no* and *wh-* questions and responding using short phrases.	Contribute to class, group, and partner discussions, including sustained dialogue, by following turn-taking rules, asking relevant questions, affirming others, and adding relevant information.	Contribute to class, group, and partner discussions, including sustained dialogue, by following turn-taking rules, asking relevant questions, affirming others, adding relevant information, building on responses, and providing useful feedback.
In addition to the standard above, you may find that you touch on the following standard as well: **P1.4.9** Expressing information and ideas in formal oral presentations on academic topics		