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Anchoring Phenomenon

A Rube Goldberg® machine stalls.



Lesson Concept

Plan and carry out an investigation that shows the cause and effect relationship between the speed of an object and the energy it possesses.



Investigative Phenomenon

In a Rube Goldberg® machine, moving objects collide with stationary objects.



Standards

Refer to Appendix 4.3 for NGSS, CCSS (ELA), and California ELD standards.

4.3 Collisions and Speed



Storyline Link

In prior lessons, students observed movement in a Rube Goldberg® machine and transitioned their conversation from contact forces to energy being present whenever there are moving objects. Students looked for cause and effect relationships that explained change within a system by identifying where the energy comes from, what the energy does, and where the energy goes.

In this lesson, students notice patterns and cause and effect relationships by observing what energy does as it transfers to describe energy in terms of speed and collisions. They plan and conduct an investigation about the relationship between speed and energy and the impact of collisions on objects. Students also construct an explanation using evidence from their investigation to support the claim that faster-moving objects have more energy. Finally, they recall the failed Rube Goldberg® machine from Lesson 2: Oops! and propose a solution.

In the next lesson, students will apply their understanding of energy to explore the transformation of energy in sound, light, or heat. They continue using cause and effect to view how energy changes.

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

265 minutes

Part I

10 minutes Engage

Part II

30 minutes Explore 1

Part III

60 minutes Explore 2

Part IV

45 minutes Explore 3

Part V

45 minutes Explain

Part VI

60 minutes Elaborate

Part VII

15 minutes Evaluate

4.3 Collisions and Speed



Materials

Whole Class

- 4.2.C1: Energy Questions (from Lesson 2: Oops!)
- 4.3.C1: Analyze Data Questions

Groups (Groups of 4)

- Chart paper or large whiteboard
- Moving objects (2 of each: marble, toy car, balls, etc.)
- Ramp (grooved meterstick or yardstick or a toy car ramp)
- Meterstick for measurement
- Textbook(s) for height

Group (Groups of 2)

- 10 marbles
- 20 dominoes
- 2 ramps (see above)
- 4 wooden blocks

Individual

- Science notebook
- 4.3.H1: Exit Ticket



Advance Preparation

1. Gather supplies
2. Have available the **Our Questions** chart and the **Our Thinking So Far** chart from Lesson 1: What's Going On? and **4.2.C1: Energy Questions** from Lesson 2: Oops!
3. Make a chart based on **4.3.C1: Analyze Data Questions** to use in Step 16.
4. Print **4.3.H1: Exit Ticket** for each student.

4.3 Collisions and Speed



Procedure

Part I

Engage (10 minutes)

Answer questions and identify possible cause and effect relationships (speed of a moving object) in a Rube Goldberg® machine.

1. Refer to the **Our Questions** chart and point out questions such as *What do we need to do to make the failed one work? If I make it go faster, could it work? How can I give it more energy so it will not stall?*
2. With a partner, ask students to discuss their ideas to answer these questions. Conduct a classroom discussion and chart their ideas.

Part II

Explore 1 (30 minutes)

Carry out investigations that explore patterns of how energy can move from place to place in moving objects.

3. Offer each set of partners the materials (10 marbles, 20 dominoes, 2 ramps (rulers), 4 wooden blocks), and ask them to investigate patterns of movement using these materials. Ask students to record their setups and their observations in their science notebook.

TEACHER NOTE

This is “constructive playtime” for students to explore the ways in which these objects interact. Don’t tell them what to do with the materials. Instead, look for students setting up and knocking down dominoes, using the marbles to knock down dominoes, and using the rulers and blocks as ramps for marbles to knock down the dominoes or collide with other marbles.

4. After about 15 minutes, conduct a class discussion and chart their ideas. Have partners share what they did and what they observed. What patterns did they notice? *ESRs: We had to push the marble harder to knock down more dominoes. We had to stack the dominoes closer together to knock more down. We didn’t knock down as many dominoes when the marble moved slowly, etc.*
5. Ask students to relate their observations to their list of ideas from Step 2 about how to make the failed Rube Goldberg® machine work. What do these observations mean? Have them share with a partner and then discuss as a class. *ESRs: If we make it go faster, it should work. If we make it go faster, it will have more energy to make it work.*
6. What is a statement the students can make about what they think is the relationship between speed and energy? *ESR: A fast-moving object has more energy than a slow-moving one.* Write the statement on the board.

4.3 Collisions and Speed

Part III

Explore 2 (60 minutes)

Collaboratively plan an investigation to explore the cause and effect relationship of the speed of an object to the energy it possesses.

7. Point to the statement the students made in Step 6 and ask how they could investigate the relationship between the speed of an object and the energy it possesses. Have students share ideas.

TEACHER NOTE

If students have planned an investigation before, they should be adept at identifying the phenomenon, the data that can serve as evidence, and understanding the idea of controls and variables. When scientists conduct an experiment, they test one thing at a time. The thing they change is called a *variable*. They want to see what happens when that one thing is changed. Everything else is controlled to be the same so that it does not influence their results.

If this is the students' first attempt at planning an investigation, take the time to help students understand these components of planning an investigation.

8. Show the materials students have available to use for their investigation (textbooks, ramps, metersticks, marbles, toy cars, and balls). Ask them to work in partners to think about what they learned in the first Explore and how they can apply that to use these materials to test their ideas. *ESRs: When the marbles went faster, they knocked down more stuff; marbles, cars, and balls moved at different speeds. More or less speed has an impact on energy and its transfer. Things that move faster go farther and knockdown things more easily.*
9. Have several partners share their ideas with the class. If necessary, ask probing questions such as:
 - a. Why are we conducting this investigation? *ESR: Trying to understand how we can make the failed Rube Goldberg® machine work; trying to see if more speed would keep the Rube Goldberg® machine from stalling.*
 - b. Ask, "What would count as evidence that more speed means more energy? Does less speed mean less energy? What data would make you think this wasn't true?"
 - c. Ask, "What would happen if you change the speed of the objects?" If necessary, guide them to think about how they can change the speed of marbles, toy cars or balls using ramps and textbooks. Ask students to think about what would happen if they pushed their object on a flat surface compared to it going down a ramp. Think about what would happen to their object if the ramp that was even higher/steeper.

4.3 Collisions and Speed

10. Ask the following questions, provide time for students to discuss, and record their ideas on the board:
 - a. Discuss the variable they think they want to change (for example, the height of the ramp).
 - b. "What will they observe/measure when they change the height of the ramp?" *ESR: How far the object traveled.* "How can they measure that distance?" *ESR: With a meterstick.* "What unit should they use?" *ESR: Centimeters*
 - c. "What do they need to control (keep the same)?" *ESR: The object, the ramp, the type of textbook, etc.*
11. Explain that the class is going to use the ideas on the board to collaboratively decide on a procedure to use for the experiment. Work with the class to determine a step-by-step plan that the class agrees will help make the results similar (standardized). Ask students why this type of procedure is important (so that others can replicate the experiment).

TEACHER NOTE

The following plan is provided as an example. Your students may construct a different way to do this investigation.

The following items are part of the plan:

- a. Help students come up with a plan that uses the textbooks to provide height to a ramp that an object will go down. Ask: "What will this help us see?" *ESR: If speed and energy are related.*
- b. Have students predict if they think height will make a difference in how far their object travels when it goes down a ramp. Allow them time to discuss. Ask students if they think this is something they can test. If so, how? *ESR: Stack textbooks on top of one another to increase the height of the ramp.*
- c. Have students consider how the books should be stacked on top of one another. Inform them that everyone needs to come to an agreement about how the books are stacked so that they are the same. Ask them why all students need to stack the books the same way. If students struggle with this, ask: "Would it be helpful to compare our results if we did not conduct the investigation in the same way?"
- d. Ask students how many times they think they need the car to go down a ramp. They may say one time. Encourage students to think about the validity of their results with one trial and how multiple trials would provide more data. Work towards an agreement of 3 to 5 trials for each ramp height.
- e. Ask students how they should collect their data. *ESR: Organized in a table, a list, a model, etc.*

4.3 Collisions and Speed

Part IV

Explore 3 (45 minutes)

Collaboratively conduct an investigation to explore the cause and effect relationship of the speed of an object to the energy it possesses.

12. Review the plan previously developed with students. Ask if there are any questions about the process or anything that may need to be changed.
13. Have students work in groups of 3 or 4 to conduct the experiment according to the plan. Monitor students to ensure they follow the plan. Make sure data is being collected and recorded.
14. After they conduct the investigation, allow students time to discuss their observations within their groups, focusing on speed and energy.

Part V

Explain (45 minutes)

Analyze data to construct an explanation of the observed cause and effect relationship between the speed of an object and its energy.

15. Create a class data chart with data from the individual groups. Ask groups to record their data on the chart.
16. As a class, discuss the questions on **4.2.C1: Energy Questions** from Lesson 2: Oops!; Where did the energy come from? What did it do? Where did it go? Then answer questions 1–3 on **4.3.C1: Analyze Data Questions**. What is the pattern they noticed? *ESR: Objects that moved faster had more energy and went farther.* What might this pattern imply?
17. Refer to the statement they made as a class in Step 6—The faster something moves the more energy it has. “What question are we trying to answer?” *ESR: Does speed increase the energy of an object?*
18. Ask the class, “What data do you have that might support this claim?” *ESR: Patterns of the data on the class chart.* “Do you have evidence from other patterns you have observed so far?” If necessary, refer them to the patterns and models they developed in Lesson 1: What’s Going On? and Lesson 2: Oops!
19. Ask, “How do these patterns support the claim?” Have table groups to share their ideas. Help students to notice that they now have two sources of data (ramps and patterns in the Rube Goldberg® machine) and in both cases, the patterns in the data indicate that things that move faster have more energy. These patterns are evidence to support a claim.

4.3 Collisions and Speed

20. Distribute chart paper to each table group and ask them to write a claim and the evidence that supports it using their discussion from Steps 17–19. Ask students to also record their claim and evidence statements in their science notebook.
21. Select several groups to share their claim and evidence statements.
22. Conduct a class discussion. “Is the evidence that was used appropriate to support the claim? Why or why not? Was the evidence sufficient? Why or Why not? What other evidence could be cited to make the claim stronger?”

TEACHER NOTE

The purpose of the claim and evidence at this point is to help students understand:

- a. raw data is not evidence; it has to be analyzed;
- b. evidence has to be appropriate to support the claim; and
- c. evidence from multiple sources is more conclusive than evidence from one source.

The evidence from the experiments/investigations/videos is appropriate to the claim. The evidence could be stronger by repeating the experiments with different materials.

Part VI

Elaborate (60 minutes)

Predict outcomes about patterns in the changes in energy when objects collide.

TEACHER NOTE

For Steps 25 and 29 have groups film their tests with a tablet if possible. In that way they can watch their recordings several times during partner discussions and the class discussion.

23. Place a stationary object at the bottom of a ramp. Ask students to work with a partner to predict what would happen if they released a moving object. Tell them to use their previous claim to generate testable questions about this system of objects.
24. Provide each table group with 2 cars and a ramp. Ask students to decide how to test their questions based on their previous investigation.

4.3 Collisions and Speed

25. Ask them to conduct the experiment, individually record their observations in a drawing, and label where the energy is changing—what did they observe? Remind students that we observe using our five senses. Then ask them to think about what they can observe using their hearing.
26. Have students partner with another student and discuss the collision in terms of energy changes. *Possible student discussion: The car coming down the ramp had energy. It hit the car at the bottom transferring some energy to it to make it move. The original car stopped, so it must have lost some energy.*
27. Distribute whiteboard and markers. Ask partners to divide the board in half and make a pictorial representation of their discussion on one half of the board.
28. Have groups change the height of the ramp. “What do they predict will happen? What is their evidence for this prediction?”
29. Ask them to conduct the experiment and record their observations.
30. Have partners discuss the collision and make a pictorial representation of their discussion on the other half of the board.
31. Select several partners to share their pictorial representations of the two experiments. “What was similar about the two experiments? What patterns did they notice?” *ESR: Energy was in the moving objects; when it was transferred more went into the moving object—less was in the object that stopped. “What was different?” ESR: The higher ramp made the car move faster, and its collision was stronger so that the car moved farther. “Is this another pattern?”*
32. Based on their data, ask students to think about what would happen if the cause (cars) were switched for balls or marbles. “Can they predict the effect? Why? How does the cause and effect relationship help them explain their prediction?”
33. ► Ask students to use their experiment’s results to describe in their science notebook what they now think about the relationship of the moving object to how much energy it possesses and how energy can be moved from place to place by moving objects.
34. Have groups add any evidence to their chart paper and provide time for students to copy their whiteboard drawings into their science notebook.
35. Focus on the **Our Thinking So Far** chart from Lesson 1: What’s Going On? and add to or refine their thinking.

4.3 Collisions and Speed

Part VII

Evaluate (15 minutes)

Use evidence based on patterns to solve a problem relating the speed of an object to the energy of that object.

36. ► Provide students with **4.3.H1: Exit Ticket** and have students individually complete it.
37. Collect **4.3.H1: Exit Ticket** to determine if students understand the three-dimensional learning for the lesson or if they need additional support/review in the next lesson. *ESR: We learned that the faster an object is moving, the more energy it possesses. When objects collide, the energy can be transferred to another object, changing its motion. In our experiment, the higher ramp made the marbles go faster and the cars go farther. We think that if the paper roll in the Rube Goldberg® machine was positioned higher, it would roll faster with more energy to hit the lever, which would knock down the wine glass and lower the trap.*

References

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rubegoldberg.com

Toolbox Table of Contents

4.3.H1	<u>Exit Ticket</u>	4.3.12
4.3.C1	<u>Analyze Data Questions</u>	4.3.13

Exit Ticket

Name _____

Ivan and Alyssa want to fix the stalled Rube Goldberg® machine that traps the monster. How can they use what they learned today to make the Rube Goldberg® machine successful? Cite evidence from your explorations to support your solution.

Analyze Data Questions

1. What patterns do you notice in your data?
2. Did some objects travel farther than others? Why?
3. Describe the relationship between the height of the ramp and the distance the object traveled.
4. Does your evidence support or refute your claim?

Appendix 4.3

Collisions and Speed

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
PS3-1	Use evidence to construct an explanation relating the speed of an object to the energy of that object. <i>[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.]</i>
PS3-3	Ask questions and predict outcomes about the changes in energy that occur when objects collide. <i>[Clarification Statement: Emphasis is on the changes in energy due to changes in speed, not on the forces as objects interact.] [Assessment Boundary: Assessment does not include quantitative measures of energy.]</i>

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

SCIENCE AND ENGINEERING PRACTICES (SEP)
Planning and Carrying Out Investigations
<ul style="list-style-type: none">Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.Make predictions about what would happen if a variable changes.Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
Asking Questions and Defining Problems
<ul style="list-style-type: none">Ask questions about what would happen if a variable is changed.Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
Constructing Explanations and Designing Solutions
<ul style="list-style-type: none">Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Analyzing and Interpreting Data
<ul style="list-style-type: none">Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and or/computation.

Appendix 4.3

DISCIPLINARY CORE IDEAS (DCI)

PS3.A: Definitions of Energy

- The faster a given object is moving, the more energy it possesses.

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. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

CROSCUTTING CONCEPTS (CCC)

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change.

Systems and System Models

- A system can be described in terms of its components and their interactions.

Energy and Matter

- Energy can be transferred in various ways and between objects.

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Common Core State Standards (CCSS)

CCSS ELA SPEAKING AND LISTENING

CCSS.ELA-LITERACY.SL.1

Engage effectively in a range of collaborations.

CCSS.ELA-LITERACY.SL.4

Report on a topic or text.

CCSS.ELA-LITERACY.SL.6

Differentiate between contexts that call for formal English and situations where informal discourse is appropriate.

CCSS ELA WRITING

CCSS.ELA-LITERACY.W.8

Recall relevant information from experiences.

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Appendix 4.3

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 <i>yes-no</i> and <i>wh-</i> 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		

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