Why do things sometimes get damaged when they hit each other?

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MIDDLE SCHOOL SCIENCE

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Broken Things

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Student Procedures

Lesson 1: What happens when two things hit each other?

Exploring an interesting phenomenon

Turn and talk

1. Have you ever seen a cell phone drop and the screen shatter? Describe your experience(s). What happened to cause it?

With your class

2. Take a vote in your class:
   - How many of us have seen it get damaged as a result of the phone being dropped and the phone hit the floor or ground?
   - How many of us have seen a phone get damaged when it crashed into something else besides the floor or ground?
   - How many of us have seen another object that was moving hit a phone and damage it?

In your notebook

3. Make a Notice and Wonder chart on a blank page in your science notebook.

What I Noticed	What I Wonder

4. Closely watch the video and record what you notice and wonder. Be prepared to share with your class.

In your notebook

5. Label a page in your science notebook "Working definition of collision," and record the definition beneath it. Leave the rest of the page blank so that you can return to revise this definition later.

Other collisions

In your notebook

6. Across the top of a two new pages in you notebook, write the title "Related Phenomena." Then on the left side of the page, write "Other collisions that damaged a fragile thing." Underneath, list other examples you have experienced where something fragile got damaged when it collided with something else. This can include any parts of it breaking and/or getting permanently bent out of shape.
   - For each thing listed, identify the objects that came into contact with each other during the collision.
   - Underline the object or objects that were moving before the collision occurred.

In your notebook

7. On the right hand page, write, "Other collisions that you were surprised did not damage a fragile thing." List examples you have experienced where something fragile collided with something else and you were surprised that it did not get damaged.
   - Identify the objects that came into contact with each other during the collision.
   - Underline which object or objects were moving before the collision occurred.

With your class

8. Share some of your examples and make a public record of them.
9. What do all the examples on this list have in common?

Navigation

With your class

10. Use 2 objects at your desk to show each type of collision in slow motion. Pause when the collision is starting.

Modeling collisions

Your teacher will pass out 2 handouts: *Initial Model: A Collision with Damage* and *Initial Model: A Collision without Damage*. You will use these handouts to develop a model to explain what is happening when two things come into contact in a collision and what happens when something is damaged. We will also develop a model to explain what happens when something is not damaged.

In your notebook

11. In the top left corner of *Initial Model: A Collision with Damage*, write down one time that you remember when at least one object was damaged in a collision between two objects. Also record which objects were moving when they collided.
12. Imagine you had a slow motion video that allows you to freeze/stop the collision at different points in time. In the box on the left, sketch and label what you think you would see happening right at the moment the objects touched.
13. In the box on the right, sketch and label what you think you would see happening a split second later, after the objects have collided.
14. Below the box, explain with words how the collision damaged one of the objects.
15. In the top left corner of *Initial Model: A Collision without Damage*, write down one time that you remember when an object was <u>not</u> damaged in a collision. Also record which objects were moving when they collided.
16. Imagine you had a slow motion video that allows you to freeze/stop the collision at different points in time. In the box on the left, sketch and label what you think you would see happening right at the moment the objects touched.
17. In the box on the right, sketch and label what you think you would see happening a split second later, after the objects have collided.
18. Below the box, explain with words why the collision did not damage either one of the objects.

Turn and talk

19. Share your initial models with a partner. Together, keep track of the similarities and differences between (1) what you think would happen at each point in time for each model and (2) your explanations for how a collision caused damage in one case but not the other.

Developing shared community norms

With your class

20. With your class, you will form a Scientists Circle to set up some norms for how the class wants to work together and learn together in science class.
21. Silently pick one norm from the sheet that you personally will work on the next time we meet.

Stop and Jot

In your notebook

22. Open your notebooks to a new page. Label the left page "What factors will determine if a collision between two objects causes damage?" Under this label, start to record a list of factors that you think will determine whether a collision ends up damaging a fragile thing or not. Only consider examples where one object is moving before the collision (types A or B) for now.

Revisiting our shared community norms

Turn and talk

23. Consider the norm that you chose to practice in class today. Share that norm with a partner. Tell your partner why that norm is important for you today.

Consensus Model in a Scientists Circle

With your class

24. Several students will share their models. As each student shares, look at your own model for similarities or differences.
    a. If something is similar, place a small check mark (✓) near what is similar.
    b. If something is different, place a question mark (?) near what is different.
25. Once your class agrees on the initial consensus model, update your Progress Tracker.
    a. Draw the initial consensus diagram in the last column.
    b. Copy the lesson question in the first column.
    c. Tape or glue the Model Tracker into your science notebook.

In your notebook

26. Turn back to the page in your science notebook titled "What factors will determine if a collision between two objects causes damage?" Take a few minutes to add to or modify your list in light of the consensus conversation we had today. Be ready to share your ideas with the class.

With your class

27. You will create a poster with your class that captures your ideas. As other students share their ideas, listen carefully to understand what they are saying. Respond productively when it is your turn to talk using phrases like these:

- I disagree with _________ because...
- I agree with __________ and would like to add to that idea...
- I have another factor to add that hasn't been said yet...

Revisiting our shared community norms

Turn and talk

28. Turn to a partner and share how you feel you did with the norm you chose to work on today. How did the norms help us talk together and come up with some ideas of what we think is happening?

Driving Question Board and ideas for investigations

With your class

29. Look back at
- your notice/wonder chart from the video,
- your initial models and our class consensus models,
- our list of related phenomena, and
- our list of factors that determine if there is damage.

30. Choose 1 or 2 questions to share with your class, and write each question on a sticky note or card. Write the question in dark marker and large enough for others to read.

31. Be prepared to post your questions to our Driving Question Board.

32. After the Driving Question Board is complete, think about investigations or data that could help answer the class's questions.

33. Share your ideas for investigations.

   a. Identify a question to answer.

   b. Describe how to investigate the question.

   c. Share what you think we will figure out in the investigation.

Lesson 2: What happens to the shape and motion of objects when they hit each other?

Navigation

You probably have some ideas about what happens to objects when they collide.

Turn and talk

1. Can you state what happens to objects when they collide in one short sentence? Try it with an elbow partner.

Investigate Dropping and Breaking

You will investigate dropping some hard objects onto fragile (but inexpensive) ones. The goal is to observe what makes things break and what might keep things from breaking.

In your notebook

2. Follow your teacher's directions to make observations while you drop things and break stuff.
3. Record your observations in your science notebook. Note any challenges you face.

Safety Precautions

CAUTION: Wear safety goggles. Don't drop any object from higher than an arm's length in front of you onto the table top (about 2 feet).

Discuss Design Challenges: Dropping and Breaking

With your class

4. What did you notice in your investigation?
5. What challenges did you face in making observations?
6. How could we study collisions more easily?

In your notebook

7. Predict what will happen to the shape of objects during a collision. Record your predictions in your science notebook.

Explore Collisions: Shape

In your notebook

8. Write the investigation question on your handout: What happens to the shape of objects when they collide?
9. Tape the handout for this investigation into your science notebook.
10. Follow your teacher's directions to complete the lab activity and record your observations.

Navigation

In your notebook

Today we investigated what happens to the **shape** of objects during a collision.

11. What other changes did you notice during the collisions besides changes to shape?

Navigation

With your class

12. Look back on your notebook from the previous lesson. What do you think might happen to objects in a collision (besides changes to their shape)?

Explore Collisions: Motion

In your notebook

13. Write the investigation question on your handout: What happens to the motion of objects when they collide?
14. Tape the handout for this investigation into your science notebook.
15. Follow your teacher's directions to complete the lab activity and record your observations.

Safety Precautions

CAUTION: Keep fingers out of the way when you are colliding carts and holding one cart still.

Interpret Collision Data: Shape and Motion

With your class

16. Share what you noticed during the first investigation. Did you **always** see a shape change? If not, when was there no shape change?

In your notebook

17. Write a summary statement describing what happens to the shape of objects during a collision.

With your class

18. Share what you noticed during the second investigation. Did you **always** see motion change? If not, when was there motion change?

In your notebook

19. Write a summary statement describing what happens to the motion of objects during a collision.

With your class

20. Discuss the following questions:
    a. Do collisions cause changes in motion? Why or why not?
    b. Do collisions cause changes in shape? Why or why not?

Lesson 3: Do really solid objects also bend during a collision?

Navigation

Turn and talk

1. In our last investigation, we saw that a lot of different things can happen to the objects involved in a collision.
   - What were some examples of an object(s) we saw bending during a collision?
   - What was the thing that pushed on those objects to cause them to bend?
   - What were some examples of the objects that we didn't see bending during the collision?

We need to investigate this further so that we can reach consensus as a class.

Preparing to Investigate Our Predictions

In your notebook

2. Label a page in your science notebook "Slow-motion collision videos."
3. Create a data table on this page to record what you notice in three different collisions.

Objects	Observations

Analyzing Video Cases

On your own

4. Watch the slow-motion video clips as a class. Record your observations for each video in the data table for each of the clips.

Arguing from Evidence

With your class

5. Share some of your observations with the class.
6. What does this tell us about whether or not solid objects bend during a collision?

Predictions

Turn and talk

7. We have observed that contact forces in a collision can cause really hard objects to bend. Do all solid objects bend when a contact force is applied to them?
8. If we applied a contact force to a piece of glass, do you think we would see it bend(deform) before it broke?
9. If we applied a contact force to the front table, do you think we would see it bend(deform)?

Laser, Glass, and Table Investigations

With your class

Your teacher will show you three demonstrations.

10. Share your observations with the class from the sponge and laser demonstration.
11. Share your observations with the class from the glass and laser demonstration.
12. Share your observations with the class from the table and laser demonstration.

Progress Tracker Update

On your own

13. Record this question on the next row of your Progress Tracker: Do all solid objects bend when a contact force is applied to them?
14. Record what you figured out from the videos and the demonstrations in class today.

Exit Ticket or Home Learning

On your own

Answer the following questions as your exit ticket:

15. Do you think applying **any amount** of force to **any solid object** will cause it to bend?

16. How does your prediction compare to the data we analyzed in class today?
17. How could we design an investigation to test your prediction?

Lesson 4: How much do you have to push on any object to get it to deform (temporarily or permanently)?

Navigation

In our last set of investigations, we found that many things that appear to be rigid actually **deform** (bend, distort, or change shape) when a contact force was applied to them.

With your class

1. Do you think applying **any amount** of force to **any solid object** would cause it to deform? For example:
   - The weight of a car pushing on blacktop?
   - A hammer pushing on a thick steel pipe?
   - A heavy machine pushing on a concrete beam?

The photo your teacher will show you illustrates one way that engineers test the relationship between the amount of force applied to an object and the deformation that occurs in that object. In the photo, engineers are doing such a test with large concrete beam. They increase the amount of downward force they are applying to the top of the beam to see how it will respond.

Turn and talk

2. Discuss this question with a partner:
   - Do you think you would see a thick beam of concrete like this bend when a force pushes down on it? Why?

Investigating Deformation and Damage in Concrete

With your class

3. Your teacher will show you a series of photos that show how a concrete beam responds to increases in the amount of downward force applied to it. What changes do you notice in the beam as the engineers apply a greater amount of downward force?

Turn and talk

4. What do you think the relationship is between amount of force you apply to an object and how much it deforms?
5. Do you think the type of material or how thick the object is affects how much it deforms when a force is applied to it?
6. How could we test this?

Investigating Deformation and Damage in Other Objects

The setup you will be using for this investigation is similar to the one we saw engineers use to test the concrete beam. However, there are a couple of differences.

With your class

7. Discuss the variables you will be testing and the variables you will keep constant.

In the handout

8. Record these variables in your student handout.

With your group

9. Use the procedure and materials provided to record your data in your student handout.
10. Graph your data after you have finished recording it.

Focal Norm for Today

On your own

11. Silently choose a norm from the norms chart that you will intentionally work on and monitor today to help our learning community grow stronger and more productive for everyone.

Analyzing and Interpreting Our Data

With your class

12. Review examples of how to develop a line of best fit for a scatter plot

On your own

13. Construct a best-fit line for your data in the handout using a ruler (or coffee stirrer) and a pencil or pen.

With your group

14. Discuss the following questions in your jigsaw group:
    - How does the shape of graph you made compare to the graphs of the materials other people tested?
    - What is similar and what is different?

Additional Data

Engineering students at a university used a machine to test what happened when forces were applied to different types of metals. The machine they used to do this was called a compression testing machine. The students tested samples of aluminum and steel.

Turn and talk

15. Do you think a graph of the amount of force applied to the material vs. the amount of deformation for these materials will be similar in shape to the graphs you made for the materials you tested in lab?

On your own

16. Read the handout and answer the questions.
17. In your Progress Tracker, record the question we were trying to figure out: **"How much do you have to push on any object to get it to deform (temporarily or permanently)?"**
18. Record what you figured out. Be prepared to share these with the whole class.

Scientists Circle

With your class

19. Get ready to meet in a Scientists Circle to develop a whole-group record of what we have figured out about the question that motivated our investigations:
    - How much do you have to push on any object to get it to deform (temporarily or permanently)?

Revisiting Our Focal Norms

20. How did you do with practicing the norm you selected to work on?
21. How did the class do as a learning community today? What did we do well? What could we improve on?

Lesson 5: How do the forces compare when objects of different speeds and masses collide?

Navigation

Turn and talk

1. What are some things that happen to solid objects when a force is applied to them?
2. What are the factors that determine how much an object deforms? Provide examples.

Comparing Forces: Different Materials - Introduction

In your notebook

3. When the phone hits the wall, do the wall and phone push on (apply a force on) each other?
4. If the wall and phone do apply a force on each other, how do those forces compare to each other? If you think the answer is “"It depends,” what do you think it depends on?

Turn and talk

5. Share your thinking with a partner.

Summary

Turn and talk

6. Do we see any patterns across the investigations?
7. Are there any rules we can come up with? Consider these questions:
    - Can one object apply a force on another object without the other object applying a force back? What is our evidence?
    - What do you think is the minimum number of objects you need in order to have a force?

Data Analysis

With your group

8. What patterns do you notice in the data?
9. How do the forces compare on each object when they interact? Are they the same or different? What evidence supports your claim?

Exit Ticket

On your own

10. Give an example of two objects that have been gently pushed together or that pull on each other.
11. Describe how the forces compare on each object.
12. Explain how you know how the forces will compare based on our investigations today.

Navigation - Cart Collisions

In your notebook

13. What are some different collision conditions that we could possibly test with each of these carts?

Navigation - Cart Collisions

Turn and talk

14. Discuss this question with your partner: "What are some different collision conditions that we could possibly test with each of these carts?"

Comparing Forces: Different Speeds

Turn and talk

15. How do the forces on objects compare when they have different speeds?
    - What is our dependent variable (what we want to measure) in this question? What are some tools we could use to measure the dependent variable?
    - What is our independent variable (what we want to change)? How many different ways could we change the independent variable to answer this question?
    - What might be some controlled variables (what things do we want to keep the same)?

Comparing Forces: Different Masses

Turn and talk

16. How do the forces on objects compare when they have different masses?
    - What is the independent variable (what we want to change)?
    - How could we change the independent variable to answer this question?
    - How many different changes would we need to try to answer this question?
    - How many times should we repeat each change to see if we get consistent results?
    - What might be some controlled variables (what things do we want to keep the same)?

Patterns in Your Data?

In your notebook

17. Write down any patterns you noticed with the data you collected.

Analyze Pooled Data

Turn and talk

18. How do the forces on objects compare when they have different speeds? What evidence supports your claim?
19. How do the forces on objects compare when they have different masses? What evidence supports your claim?
20. Was the pooled class data helpful in making a claim? Why or why not?
21. Did we gather enough evidence to answer our investigation questions? Why or why not?

Force Diagramming "Rules"

In your notebook

22. List the steps that you can take to draw a force diagram in your lab notebook.

Turn and talk

23. Discuss the steps that you can take to draw a force diagram with a partner.

Progress Tracker

In your notebook

24. In the "What I Figured Out" column, draw pictures, write in words, or use bullet points.

Exit Ticket

On your own

25. Choose any collision case that we explored today for your exit ticket.
26. Explain how the forces will compare between the two objects.
27. Provide specific evidence from our investigation that supports your claim about how the forces will compare.
28. Draw a force diagram for two colliding objects of different materials of your choice. Remember to
    - raw really simple objects,
    - use motion lines to indicate if the object is moving,
    - color code each object (Left = Blue and Right = Red),
    - include color coded arrows that indicate the direction of the force on each object and the amount of force on each object. Draw only the forces that help explain what is happening, and
    - include labels (Force FROM ______ ON ______).

Lesson 6: How do the forces compare when objects made of different materials collide?

Navigation

Turn and talk

1. What did we learn about how the forces compared between two objects that collided with different speeds?
2. What did we learn about how the forces compared between two objects that collided with different masses?

Navigation

Turn and talk

3. What happens to all objects, even really rigid ones, when forces are applied? What was our evidence?
4. What happens when more force is applied to an object?
5. We have tested how different speeds and different masses impact the force on each object. What is left for us to investigate?

Comparing Forces: Different Materials - Introduction

In your notebook

6. What is the independent variable in this investigation?
7. What is the dependent variable in this investigation?
8. What tools should we use to measure the dependent variable? What measurements will we look for on these tools to help us answer our question?
9. What tools should we use to change the independent variable?
10. How might we collect enough data to answer the question?

Comparing Forces: Different Materials - Introduction

Turn and talk

11. Share your thinking with a partner.
12. With your partner, come up with a way that our class could design an investigation to test this question.

Comparing Forces: Different Materials - Procedure

In your notebook

13. Report the results of your group's investigation on your handout.
14. Copy the group results as they come in on your handout.

Comparing Forces: Different Materials - Analysis

With your group

15. What patterns do you notice in the data?
16. How do the forces compare on each object in a collision when the objects are made of different materials? What evidence supports your claim?
17. Did we gather enough evidence to answer our investigation question? Why or why not?

How Do the Forces Compare on Each Object?

With your class

18. How do the forces compare on each object?
    - Golf ball and golf club
    - Baseball and bat
    - Bug and car windshield

How Do the Forces Compare on Each Object?

On your own

19. Come up with your own example of objects with different materials colliding.

Home Learning

Home learning

20. Choose any two objects made of different materials to collide besides the examples discussed today.
21. Explain how the forces will compare between the two objects.
22. Provide specific evidence from our investigation that supports your claim about how the forces will compare.
23. Draw a force diagram for two colliding objects of different materials of your choice. Remember to
    - draw really simple objects,
    - use motion lines to indicate if the object is moving,
    - color-code each object (Left = Blue and Right = Red),
    - include color-coded arrows that indicate the direction of the force on each object and the amount of force on each object. Draw only the forces that help explain what is happening, and
    - include labels (Force FROM ______ ON ______).

Lesson 7: How does solid matter push back?

Navigation

With your class

1. What do we know about how much two things in a collision push on each other?
2. What other things can you think of that can push but aren't alive? With your class, make a record of our ideas on chart paper.

Observing Springs

With your group

3. Label a new page in your science notebook with the title "Observing Springs." Record your responses to these questions underneath:
   1. What do you have to do to get the spring to push?
   2. What do you have to do to get the spring to push harder?
   3. What do you notice about how the spring looks when it is pushing harder?

Matter Up Close

With your class

4. What do you think that matter is doing on a particle scale when it gets squished?

With your group

5. How we can model matter pushing back on a particle scale after being deformed?

Adding to Our Progress Trackers

Turn and talk

6. How will we represent matter "pushing"? What forces do we need to represent?

In your science notebook

7. Add your ideas to your Progress Tracker.

Analogy Map

On your own

8. Draw and fill out an analogy map like the one below to show how the clay/springs model is like matter on a particle scale when it is deformed. Fill out the last column to show why the clay/springs model is not like matter on a particle scale.

Part of model	**Part of phenomenon**	**Are alike because...**	**Are not alike because...**
Clay	Particles		
Springs			
Pushing on the model			

Lesson 8: Why did my phone break?

Navigation

Recall that at the start of this unit, we considered situations where we saw objects break and situations where we saw objects not break. We are going to investigate a situation in which there was a terrible collision between a phone and a TV.

In your notebook

1. Write the three possible outcomes (Outcome 1, 2, and 3) on your *Gotta-Have-It Checklist*.

Your teacher will show you how to use your Progress Tracker and science notebook to find key ideas you have learned in this unit so far.

Develop Gotta-Have-It Checklist

With your group

2. Identify and write key ideas that you think are necessary to help you explain Outcomes 1, 2, and 3 on your *Gotta-Have-It Checklist*.
3. Write your list of key ideas on chart paper and post it in your classroom as your teacher instructs.

With your class

4. Participate in a Gallery Walk. Use sticky notes to leave suggestions of key ideas for other groups. Write key ideas you want to add to your list on a sticky note for your own group.
5. Participate in a Consensus Discussion with your class about the key ideas that should be on your Gotta-Have-It Checklist.

Developing Explanations

With your group

In your notebook

6. Use the ideas from your *Gotta-Have-It Checklist* and evidence from your investigations in Lessons 1-7 to develop an explanation for Outcome 1: The phone AND the TV break in the collision.

As you use an idea from the checklist, write it in parentheses after the sentence where you used it, and check it off your list.

Consensus Discussion about Outcome 1

With your class

7. Gather in a Scientists Circle and share your ideas with your class about how to best explain Outcome 1.
8. When your class comes to consensus on an explanation, write the explanation in your science notebook.

Prepare for Assessment

On your own

9. Following your teacher's directions, write a scenario on your *Lesson 8 Assessment*. Draw a picture to help you visualize the collision if it helps. Be sure to indicate which object (if any) breaks during the collision.
10. Write a question about your collision on your *Lesson 8 Assessment*.
11. If you selected an alternate scenario, be sure to have your teacher check it before you go home.
12. Complete your *Lesson 8 Assessment* at home.

Lesson 9: How can we get something to do as much damage as possible in a collision?

Navigation

Turn and talk

1. Brainstorm some factors that we think will affect the size of the force in a type B collision, where a moving object collides with a fragile object that is not moving.

Stop and jot

2. We did a similar brainstorm in the anchor. How have your ideas changed?

With your class

3. Brainstorm some factors that we think will affect the size of the force in a collision where a moving object collides with a fragile object that is not moving.

Preparing Our Notebooks for the Speed Investigation

With your class

4. Turn to a new page in your notebook. Copy the investigation question at the top of the page.
5. Cut out and paste or tape the data table from the handout underneath the investigation question.
6. Copy the independent variable (the one that you are changing in-between trials) into your data table. Then copy the dependent variable (the one that you are measuring the impact on) into your data table.
7. What is the controlled variable (the one that you keep the same)? How will you keep it the same? Discuss with your class.
8. Paste or tape the "Procedures" handout into the right page of your science notebook.

Doing Our Investigation

With your group

9. Follow the procedures for the speed investigation.

Exit Ticket

In your science notebook

10. Respond to the following as an exit ticket: “What patterns did you notice in the data?”

Navigate: Looking for Patterns

On your own

11. Open up your science notebook to the data and insert a bookmark so that you can flip back to it easily.
12. On a new page, turn your notebook sideways. Leave the top page blank. Label the bottom page “Speed Investigation.”
13. In the left column, record a pattern you notice.
14. In the right column, **on the same line as the pattern that you noticed**, record what you think the pattern means.

With your group

15. Share the pattern(s) you recorded and what it (they) mean.

Planning and Doing Our Own Investigations: Mass Investigation

With your class

16. What is the question we want to answer with this investigation?
17. Record the investigation question that your class develops at the top left of a new page in your science notebook.

With your group

17. Make a data table under the investigation question. Decide on how many trials to do for each condition, and create the appropriate number of rows.
18. What is the **independent variable** (the one that you are changing in between trials)? What is the **dependent variable** (the one that you are measuring the impact on)? Record these in your data table.
19. What is the **controlled variable** (the one that you keep the same)? How will you keep it the same? Discuss in your groups.
20. Write out the procedures you will follow on the right page of your notebook, including how you will keep your controlled variable the same.
21. Carry out the investigation.

Recording Patterns

On your own

22. Open up your science notebook to the data from the mass investigation and insert a bookmark.
23. On the same page where you recorded the patterns you noticed in the speed investigation, turn your notebook sideways and make a table above the previous table on the empty page. Label the page “Mass Investigation.”
24. In the left column, record a pattern you notice. In the right column, **on the same line as the pattern that you noticed**, record what you think the pattern means.

With your group

25. Share the pattern(s) you recorded and what it (they) mean.

Adding to Our Progress Trackers

Turn and talk

26. What did we figure out?

On your own

27. Add your ideas to your Progress Tracker.

Navigation

With your class

28. Was it easy to control the speed of the cart? Why or why not?

Lesson 10: How do different amounts of force on an object change its motion?

Navigation

With your class

1. What were we doing to speed up the objects (carts) in the last lesson?
2. If we want a reliable way to speed up an object the same amount every time, this might not be the most reliable method. Why?

Predictions

With your class

3. If we used a spring scale attached to our track to launch a cart, do you think it would provide a reliable way to control how much the cart is sped up? How could we find out?
4. How could we use a two-track launcher system like this to investigate the question "***How do different amounts of force on an object change its motion?***"

Investigating Deformation and Damage in Other Objects

With your group

5. Title a blank sheet of notebook paper with our investigation question: "**How do different amounts of force on an object change its motion?**"
6. Determine the independent, dependent, and controlled variables and record these underneath the title.
7. On the top half of a loose sheet of paper, record your plan for calibrating your two launchers. Remember to include the answers to these questions:
   - What amount of force will you use in both launchers for this calibration test?
   - How many times (trials) will you run these launchers to determine whether or not both systems produce repeatable and reliable results?
8. Create a data table to record different combinations of force that you want to apply to one cart vs. another.
9. Provide space to record the results for the number of times (trials) you will run the launchers with each combination of forces you want to try in order to produce repeatable and reliable results.

Carry Out the Investigation

With your group

10. Carry out the investigation in your groups.

Progress Tracker

On your own

11. In your Progress Tracker, record the question that motivated the lab you just carried out: **"How do different amounts of force on an object change its motion?"**
12. Record what you figured out. Be prepared to share with the whole class.

Navigation

We have said more mass of a moving object causes more damage and more speed does, too. So does more mass end up moving just as fast when we launch it?

With your class

13. If we launched this cart with your same launchers, do you think it would speed up as much as the carts you used? Why or why not?

Lesson 11: How does a force change the motion of something that has a little mass compared to something that has a lot of mass?

Navigation

We learned that using a small force on a light object and a larger force on a more massive object showed that bigger forces don't always mean more speed. Our thinking is incomplete, and we need to test the relationship between force and its effect on motion when we try to speed up objects with different masses.

Turn and talk

Think back to our previous investigation.

1. How do you think launching this cart from the same launcher would compare to the other carts you used? Would its motion be the same?

Thinking about Our Evidence

With a partner

We know that more force results in greater change in motion if we keep the force the same, but what if we **change** the mass?

2. What kind of investigation would you want to do to figure this out?

Planning and Carrying out an Investigation

With your group

3. Work with your group to design an investigation to answer this question: How do you think force changes the motion of something that has a lot of mass compared to something that has a little mass?

In your notebook

4. Add your investigation procedures and a data table to your notebook on a page titled "Effect of a force on the motion of objects with different masses."

Looking for Patterns in Data

With a partner

5. Discuss with a partner:
    - What patterns did you notice in your data?
    - What claim can you make about the relationship between force applied to an object, the mass of the object, and how the motion of the object changes?

Navigation

Turn and talk

6. We have figured out a lot of things about how large forces and small forces act on a constant mass and about how a constant force acts on heavy things and light things.
    - What do you think are the most important things to consider if we want to make a really awesome destructor?
    - Be prepared to share these ideas with the whole class tomorrow in the Scientists Circle.

Lesson 12: How do we get a massive object moving as fast as possible?

Navigation

We figured out that a larger mass is more destructive and greater speed is more destructive. We also figured out that we need more force to speed up or change the motion of something heavy.

With a partner

Think back to the results of our races with carts of different masses.

1. How can we get a massive object moving as fast as possible?

Scientists Circle

With your class

Let's meet in the Scientists Circle and add to our Progress Trackers to develop a whole-group record of what we agree on and where we have competing ideas.

2. What do we all seem to agree on?
3. What do we disagree on?
4. What are some new ideas that we may want to consider?

Driving Question Board

With your class

We have figured out so much! Let's revisit our DQB and see if we can answer any of our questions.

5. Look over all the evidence you've collected and chose 3 questions you can answer.
6. Write the answers with supporting evidence in your notebook.
7. Be prepared to share these ideas with the whole class.

Exit Ticket

On your own

8. Work independently to complete the exit ticket according to your teacher's instructions.

Navigation

Turn and talk

9. What were we wondering about in the first lesson?
10. What were we trying to protect?
11. What ideas do we have and can we explain why they might work?

Lesson 13: How can I save my phone from destruction?

Navigation

You read about bike helmets for home learning. Reflect on that reading and what you have been learning about phones in collisions.

With your class

1. How is protecting a phone like protecting your head in a collision?

Turn and talk

2. What are some materials you could use to protect objects in a collision?
3. What do you think those protective objects have in common?

Investigate Padding

Turn and talk

4. What do you notice about the macroscopic and microscopic images of padding?
5. What do you wonder about the images?

With your class

6. How might the track with sticky notes be like the microscopic images of padding?

Turn and talk

7. Explain how foam padding might protect a delicate object in a collision.

Brainstorm Criteria for Design Challenge

With your class

8. Participate in a class discussion to select the design criteria for a phone protector.

Design Phone Protectors

With your group

9. Design your phone protector.
    a. Make a sketch.
    b. Estimate the cost of your phone protector.
    c. Describe why your phone protector will work.
    d. Create a poster on chart paper that shows items a-c. As you describe why your phone protector should work, include points such as
    - forces involved in the collision (draw a force diagram),
    - elastic limit of the phone, and
    - strategies for reducing the forces during the collision.

Participate in a Gallery Walk

With your class

10. Participate in a Gallery Walk to see other students' designs.
    a. Leave constructive feedback for your peers on sticky notes.
    b. Write ideas you like on a sticky note for yourself.

In your notebook

11. In your science notebook, write your ideas for how you might revise your design.

Scientists Circle

With your class

12. Participate in a class discussion to explain how phone protectors work.

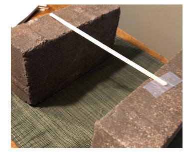
In your notebook

13. Record your own explanation for how phone protectors work in your Progress Tracker.
14. Review ideas in your Progress Tracker to prepare for a unit test.

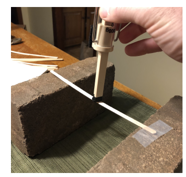
References

Investigation Procedures

1. Record the material your group is testing in column A of your data table. Adjust your push-pull spring scale so it reads 0 N when no force is applied to it.
2. If you are testing two layers, tape the edges of your two layers together. Use a pencil to mark the center point of your object where you will apply a force using the spring scale.
3. Place your material between two bricks with 1" of each edge of the material overlapping the brick. Tape down one end of the material to the brick surface.



4. Measure the height of the center point of your object above the table. Record this in *Column C*, row 1 of the data table in the *Results* handout.
5. One member of the group should place a spring scale against the center point of the object and push down with 1 N force and hold it at that level. Another group member should measure the height of the beam with the force applied to it. Have a third member record that height in column D, and calculate the deformation in column E of the data table.

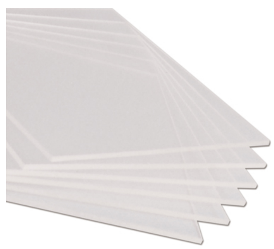


6. Remove the force from the object. Record whether the object returns to its original shape when the force was removed in column F.
7. Repeat the last two steps for a new data point. Some should be for different amounts of force than ones you already tested. However, reserve at least 2 measurements to repeat a previously tested amount. Don't forget to record the height before you apply the force in column C and the amount of force you are apply in column B.
8. When you have the table complete, have other members of the group record and make a copy of the data in their own data tables.
9. Label the x-axis of your graph with the independent variable for this experiment. Label the y-axis of your graph with the dependent variable for this experiment. Label the graph title with the type of material and thickness (1 layer thick or 2 layers thick) you tested.
10. Use the symbols in the key to plot this data:
(value from column B, value from column E).

Designing a Phone Protector: Materials Reference Sheet

We have a problem. We want to protect our phones! Here are some materials you might use to do just that. Use this information to estimate the cost of your design. If there are materials you would like to use that are not on this sheet, then please find a cost estimate for those materials.

Material name	Image	Dimensions	Cost
Foam wrap		12 in x 12 in x ⅛ in (each sheet)	$10.99/50 sheets
Bubble wrap		12 in x 12 in x 3/16 in (each sheet)	$9.09/175 sheets
Brown craft paper		17.75 in x 100 ft (roll)	$12.89/roll
Packing peanuts		Bag that will fill a box of size 0.6 ft x 1 ft x 1 ft	$9.99/bag

Material name	Image	Dimensions	Cost
Foam pouches		20 cm x 20 cm (each bag)	$4.99/20 bags
Clear plastic sheet		21 in x 51 in x .02 in (each sheet)	$10.18/sheet

Readings

Anatomy of a Bike Helmet


This picture shows a bicycle helmet that was damaged when a rider hit his head during a fall.

Have you ever fallen while riding a bicycle? Hopefully you were wearing a helmet! Hitting your head on a hard surface like the road or a sidewalk might result in a serious brain injury. For example, the occipital lobe of your brain is located in the back of your head and is where your vision is processed. A hard blow to the back of your head could leave you with severe vision loss or even total blindness. The front of your brain, called the frontal lobe, is responsible for functions such as speech, some motor skills, memory formation, decision-making, and many others. Hitting the front of your head after a fall from a bicycle could result in problems with speech, poor coordination, or difficulty remembering things or making decisions.

Helmets, designed specifically for bicycle riders, are important safety gear that can protect your brain in a fall or an accident. In fact, wearing a helmet is associated with a 60% decrease in serious head injuries for riders who hit their heads during falls or accidents.

So what makes a helmet effective? The Consumer Products Safety Commission is the regulating agency in the United States that determines safety standards for many products, including bicycle helmets. There are many choices in helmets, and prices range from very expensive to very affordable. Expensive helmets are not necessarily better. Low-cost helmets that meet the safety standards are good choices for bicycle riders. When choosing a helmet, you should always make sure that it meets these standards. There are other considerations for helmet manufacturers and bicycle riders, too. A helmet should

- fit snugly and stay in position when you are moving around,
- have easily adjusted straps,
- be lightweight and comfortable, and
- not block your vision in any way.

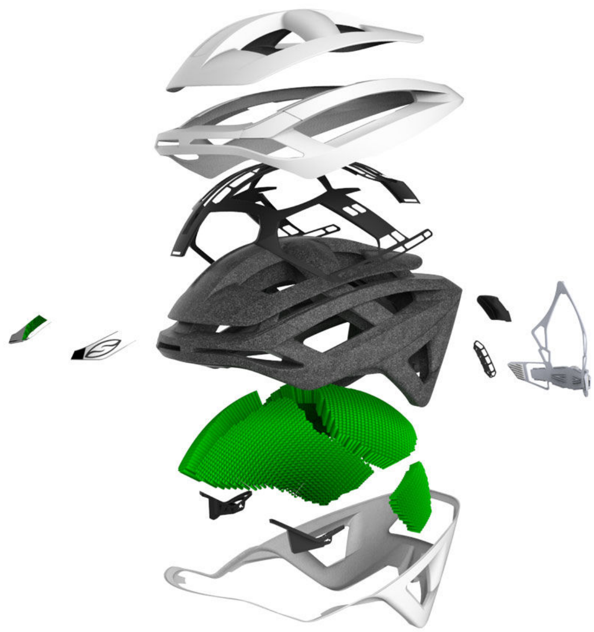
You may be wondering why helmets look the way they do. The thickness and shape of helmets are purposely designed to protect your brain, but manufacturers also want helmets to look cool so consumers will wear them. Let's take a look at the structure of a bicycle helmet.

Helmets have hard outer shells made of lightweight materials like polycarbonate or fiberglass. There are often vents in the outer shell to allow air to flow over the cyclist's head. This hard layer can crack during a collision.

Helmets have an inner layer of crushable foam. The foam has air pockets that are designed to squish during a collision--but not too quickly!

Helmets have internal mechanisms like adjustable straps and pads to ensure a snug and stable fit for many different head sizes.

If you have a bicycle helmet that doesn't meet current safety standards or that doesn't fit well, you should replace it. You should also replace your helmet if it's been in a collision because it might not effectively protect you in another collision.



Helmets are made of many parts.

Would small cracks in the outer shell of a helmet make it unsafe?

If the inner foam layer of a helmet was crushed in one spot, would the helmet be unsafe?

Why might it be a good thing for a helmet to be designed to break during a collision?