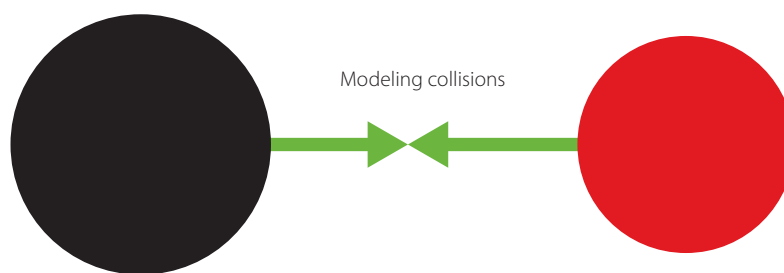


Unit 1

Contact Forces:

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

Student Procedure Guide



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Contact Forces:

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

Student Procedure Guide

Core Knowledge Science



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Contact Forces

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

Exploring a Phenomenon

Turn and talk



1. Have you or someone you know ever broken a phone? Describe your experience(s). What happened to cause it to break?

Be ready to share your experiences with the class!

With your class



2. Discuss the following questions with your class:

- What damage to phones have you seen or experienced?

A few volunteers will use a CD case in place of a phone to show the class what happened to the phone.

Your teacher will draw a model to represent what happened as you share.

Other Collisions

Writing in Science



3. Think about other collisions you have heard about or experienced. As you brainstorm other collisions,

- list collisions where objects were **damaged** during the collision on a **red** index card and
- list collisions where objects were surprisingly **not damaged** on a **green** index card.

4. Do the following on each index card:

- Identify the objects that came into contact with each other during the collision.
- Underline which object or objects were moving before the collision occurred.

On your own



5. Look at your cards. Are your collisions examples of collision type A, B, or C? Label your red and green cards with "A", "B", or "C".

With a partner



6. Listen for the card color the teacher asks you to get out first. Look at the scenario type on that card, then go to the area of the room that matches your card.
 - While you are in your area, share your collision with a partner.
 - Look for any similarities and differences in how the collisions occurred.
 - How did damage (or no damage) occur?

Identifying Factors in a Collision

In your notebook



7. Create a T-chart in your notebook.

Patterns in collisions	Factors and variables that might cause damage in a collision

- Look at the collisions we have identified from our experiences.
- What patterns do we notice between collisions and collision types?
- What factors and variables might have caused the items to get damaged or not get damaged in a collision?
- Record them on the T-chart.

Modeling Collisions

In your notebook



8. Your teacher will pass out the handout *Initial Model: Objects During Collisions*. Use this handout to develop a model to explain what is happening when two things come into contact in a collision and what happens to cause one or both things to be damaged or surprisingly not damaged. Choose an example from the Related Phenomena poster to model.
9. In the top line of *Initial Model: Objects During Collisions*, write down the two objects that collided. Also record which scenario you chose and whether there was damage.
10. Imagine you had a slow-motion video that allows you to freeze or 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 touch.
11. 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.
12. On your next handout, *Object Interactions During a Collision*, think about what happened between time point 1 and time point 2. Record what you think was happening at the level we can see *and* at the level we cannot see. Describe what would have to happen to change the outcome of the collision to the opposite outcome: for the object to be damaged or to have no damage.

Sharing Initial Models

Turn and talk



- 13.** With your class, form a Scientists Circle. Find a partner and compare your models.
 - Discuss the following questions:
 - How did you represent things similarly or differently as they collided?
 - Why did you represent them acting the way they do?
 - Look for factors and variables that you have in common or different that may have contributed to the damage (or lack of damage).
 - Put a ✓ on your paper where you and your partner agree on ideas.
 - Put a ? next to areas where you disagree on ideas or have questions.

Developing Shared Community Norms

With your class



- 14.** With your class, set up some norms for how the class wants to work together and learn together in science class.
- 15.** Silently pick one norm from the sheet that you personally will work on today.

Consensus Model in a Scientists Circle

Scientists Circle



- 16.** The goal of this discussion is to come to consensus on what we believe is happening at the moment of collision and a split second later. During the discussion, areas that we do not agree on will also be identified so they can be investigated later.
- 17.** Several students will share their models. As each student shares, look at your own model for similarities or differences.
 - If something is similar, place a small check mark (✓) near what is similar.
 - If something is different, place a question mark (?) near what is different.
- 18.** 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.

Developing Questions

Writing in Science



- 19.** Label a new page in your science notebook “Initial Collision Questions”. Look back at the Consensus Model for Collisions poster. What new questions do you have about the objects in a collision and the changes that might happen during a collision?

Write your new question(s) down in your notebook.

Updating Patterns in Collisions Chart

In your notebook



- 20.** Turn back to the page in your science notebook with the “Patterns in collisions” T-chart. Take a few minutes to add to or modify your list with your new ideas after the consensus conversation we had today.

Share with the class any new factors or variables that should be added to the T-chart.

Tonight, consider the patterns, factors, and variables in a collision. Be ready to come to the next class meeting with some potential new ideas that may not already be represented on our charts and posters.

Selecting a Focus Norm

With your class



- 21.** Look over the Classroom Norms chart again.
- 22.** What norm should the class work on as a group? Take a vote to determine what norm we will focus on today.

Revisit factors and variables.

With your class



- 23.** Look back at your “Patterns in collisions” chart.
- 24.** Do we have anything we can add to our Factors and Variables poster?

Developing Additional Questions

Writing in Science



- 25.** What new questions do you have about the patterns in collisions and factors and variables that might affect damage in a collision?
- 26.** Write the question(s) down on your index cards or sticky notes.
- Write one question per sticky note.
 - Write in marker—big and bold.
 - Put your initials on the back of each note in pencil.

Driving Question Board and Ideas for Investigations

With your class



- 27.** Look back at your “Patterns in collisions” chart and questions. Choose 1 or 2 questions to share with your class.
- 28.** Be prepared to post your questions to our Driving Question Board.
- 29.** If another student has shared the same question that you have, try to share a different question that has not been shared.
- 30.** After the Driving Question Board is complete, think about investigations or data that could help answer the class’s questions.
- 31.** 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.

Revisiting Our Shared Community Norms

Turn and talk



- 32.** 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?

Lesson 2: What causes changes in the motion and shape of colliding objects?

Navigation

Many of our ideas for future investigations were related to trying out some collisions ourselves.

Turn and talk



1. What sorts of things would we want to observe more closely in a collision that may or may not result in damage?

Investigate dropping and breaking.

With your group



2. Follow your teacher’s directions to make observations while you drop things and break stuff.
 - Record observations in your science notebook.
 - Create a T-chart in your notebook and record any **challenges** you face and any new **questions** that emerge.

Description of collisions	Challenges or questions

Discuss design challenges in dropping and breaking investigation.

With your group



3. Discuss the following questions with your group:
 - What did you notice about the motion or shape of colliding objects?
 - What challenges did you face?
 - How could we study collisions more easily?

Be ready to share your ideas with the class.

With your class



4. Consider the available equipment that can be used to address the challenges you experienced making observations of collisions.
 - How would investigating collisions using this equipment help us address some of the challenges we encountered in the previous investigation?

Turn and talk



5. Work with your class to define the collision system and the subsystems that exist using the available equipment.
6. When the objects that are part of the two subsystems make contact during a collision, what sort of changes do you think you might observe in those objects or in the subsystems they are attached to?

Explore horizontal collisions.

In your notebook



7. Your teacher will pass out the handout *Exploring Horizontal Collisions*.

- Write the investigation question on your handout: **What happens to the motion and shape of the objects (and the subsystems they are part of) when they collide?**

With your group



8. Work through at least 3 stations with your group:

- You will have three minutes at each station.
- Record data on your handout.
- If your group misses a station or is uncertain of the results and doesn't have time to repeat the investigation at a particular station, add question marks to the corresponding cells of your data table.
- Add your handout to your notebook when you are done.

Navigation

In your notebook



9. In your notebook, look over your observations from our investigations.

- Write a response to this question: *What happens to the motion and shape of the objects (and the subsystems they are part of) when they collide?*
- Be ready to share your ideas with the class next time.

Navigation

Work with your class to identify patterns in data related to changes in motion and shape that occur during collisions.

With your class



10. Share your response from the question: *What happens to the motion and shape of the objects (and the subsystems they are part of) when they collide?*

Make observations of slow-motion videos.

In your notebook



11. Set up a T-chart in your notebook to record observations of slow-motion videos. Title your chart: "Observing Collisions in Slow Motion".

Collision type	Observations

Develop cause-effect statements.

Writing in Science



12. Develop cause-effect statements to account for what might be causing the changes in motion and changes in shape of colliding objects.

- When objects/systems collide, _____, which results in a change in motion.
(cause) (effect)
- When objects/systems collide, _____, which results in a change in shape.
(cause) (effect)

Be ready to share your ideas with the class.

Update your Progress Tracker.

In your notebook



13. Create a 2-column chart in the Progress Tracker section of your notebook.

- Write the question we are working on in the left column: *What causes the changes in motion and changes in shape of colliding objects?*
- Write what you figured out in the right column.
- Use words and/or pictures and take as much space as you need to record your thoughts.

Question	What I figured out

Be ready to share your thinking with your classmates in a Consensus Discussion.

Brainstorm materials to test.

With your class



14. Discuss with your class:

- Does the force from a collision always cause shape changes in the objects that collide, but sometimes we just can't see or detect it?

In your notebook



15. Brainstorm some types of objects or materials that you know of that are very rigid that could be useful to test in order to investigate our new question.

Lesson 3: Do all objects change shape or bend when they are pushed in 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 was the question we took a poll on at the end of our last class that we decided we needed to investigate further about shape changes in collisions?
 - What were some types of objects or materials you brainstormed in your notebook that are very rigid and that could be useful to test in order to investigate this question?
2. Do you think those materials we didn't see bend with our own eyes are actually bending, but it's just really hard to see?
3. Do you think you would see things like glass, steel, or golf balls bend when something pushes on them in a collision if you could zoom in really close or watch them in slow motion?

Making an Initial Claim

On your own



4. Look at the top of your paper and fill in your initial claim with your current thinking:
 - All solid objects **do** bend or change shape when pushed in a collision.
 - All solid objects **do not** bend or change shape when pushed in a collision.

Preparing to Investigate Our Claims

On your own



5. Watch the slow-motion video clips as a class. Watch the videos the first time they are played. The second time you see the clip record your observations on your handout.

Claim and Observations Organizer

My initial claim		
All solid objects _____ bend or change shape when pushed in a collision.		
Data source	Observations	Draw this support or refute your claim?
Slow-moving car colliding with a stationary car		
Moving golf club colliding with a stationary golf ball		
Moving baseball colliding with a stationary bat		

Comparing Observations to Our Claim

On your own



6. Look at your "Observations" column.
 - Did your observations you just made about each video support (agree with) or refute (disagree with) your initial claim?
 - Write "support" or "refute" in the last column.

Take a poll—arguing from evidence.

With your class



7. Take a class poll:
 - Do really solid objects bend or change shape when pushed during a collision?

What is your reasoning for your answer? Be ready to share with the class.

Make predictions.

Turn and talk



8. We've seen that pushes in a collision can cause many solid objects to bend or change shape.
 - If we pushed on something like a piece of glass on our phone screen, do you think we would see it bend or change shape before it broke? What about thick glass?
 - If we applied a contact force to a thick piece of concrete, would you see a change in shape before it breaks?

Laser, Sponge, and Glass Investigations

With your class



9. Your teacher will show you two demonstrations.
10. Write "sponge and laser" in the first empty box in the first column.
11. Watch the demonstration and record your observations.
12. Write "glass and laser" in the next empty box in the first column.
13. Watch the demonstration and record your observations.

Take a poll—make predictions.

With your class



14. We saw that rigid items like glass also bend when a contact force is applied in a collision.
 - Do you think that really solid objects like concrete would also bend before they break in a collision? Why or why not?

- Let's take a class poll—give a thumbs up or down.
 - Thumbs up - I think it will bend before it breaks.
 - Thumbs down - I think it will break, not bend.

Concrete Beam Load Test

On your own



15. Fill in the third empty box on the left of your handout with "concrete load images."
16. Your teacher will show you several images of a concrete beam load test. This test was done over the course of 5 minutes. Look at the images and record your observations on the last row of your handout.
17. Determine if the observations from the last 3 sources would support or refute your claim. Record "support" or "refute" for each in the last column.

Arguing from Evidence

On your own



18. Review the initial claim you made at the beginning of class. Write your original claim in your notebook. Record in your notebook your answers to these questions:
 - Do the data support or refute your original claim?
 - How does the evidence from our investigations help support or refute your original claim?

Take two polls.

With your class



19. Take two polls:
 - Were you surprised by the results of the concrete beam test?
 - Thumbs up - I *was* surprised.
 - Thumbs down - I *was not* surprised.
 - Do you think that the concrete beam began to deform with a small amount of contact force at the start of the test or did it take a lot more force to start bending it?
 - Thumbs up - Yes, I think the beam began to deform with a small amount of contact force.
 - Thumbs down - No, I do not think the beam began to deform with a small amount of contact force.

Turn and talk.

Turn and talk



20. Turn and talk with a partner:

- Do you think applying any amount of force to any solid object would cause it to bend?
- How could we design an investigation like the engineers did with the concrete beam test to figure out if any amount of force would cause any solid object to start bending or change shape?

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

Navigation

In our last lesson we wondered if applying any amount of force to any solid object would cause it to bend.

Turn and talk



1. What were some of your ideas for how we could investigate if any amount of force would cause any solid object to start bending or change shape?

Plan an investigation: material deformation lab.

In your notebook



2. Follow your teacher's directions for adding your handout *Independent, Dependent, and Controlled Variables* to your notebook and recording the investigation question: *How much do you have to push on any object to get it to deform (temporarily vs. permanently)?*

With your class



3. Work with your class to determine the independent, dependent, and controlled variables in the investigation.

Material deformation lab: collect and analyze data.

With your group



4. Use the procedures and materials provided to collect and record data on your handout *Deformation Results*.
5. Graph your data according to your teacher's directions after you have finished recording it.

In your notebook



6. Draw a line of best fit for your own data on handout *Deformation Results*.

Turn and talk



7. How do you think the trends in your data will compare to groups that tested different beam thickness or a different material?

Comparing Patterns

With your group



Follow your teacher’s directions for sharing data with other groups. Discuss the following question with your jigsaw group:

- 8. How do the trends in the graphs for different beam thickness or different materials compare to different groups?

Making Predictions

Turn and talk



- 9. Just like the concrete beam data we saw earlier, scientists have studied other materials. Let’s see how the patterns in our data compare to data collected by engineers when they tested different metals. Discuss the following question with a partner:

How do you think a graph of the amount of force applied to the material vs. the amount of deformation for these materials will compare in shape to the graphs our class made?

On your own



- 10. Read and answer the questions on *Results from other materials tests* individually.

Update Progress Tracker.

In your notebook



- 11. In your notebook, prepare a two-column Progress Tracker entry and record the lesson question in it:

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

- 12. Record what you figured out.

Question	What I figured out

Update Class Progress Tracker.

With your class



- 13. Meet in a Scientists Circle and develop a record of the sources of evidence and what you all have figured out in relation to the lesson question:

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

Argue from evidence: What do you think?

In your notebook



- 14.** A technology company claims to have designed a phone with an unbreakable and foldable screen.

Answer the following questions in your notebook:

- Do you think this is possible?
- What do you agree with? What do you disagree with?
- What evidence do you have to support your thinking?
- How would you explain your thinking to a partner?
- How would your partner know that you listened to and tried to make sense of their thinking?

Navigation

Turn and talk



- 15.** We've been using forces to explain deformation of objects in a collision (or any time they make contact).

Review the images on the slide and discuss the following questions with a partner:

- Where are the forces in these two collisions?
- What is doing the pushing and what is getting pushed?

Lesson 5: How does changing the mass or speed of a moving object before it collides with another object affect the forces on those objects during the collision?

Whole Group

We have been using forces to explain deformation of objects in a collision (or any time they make contact). In golf, the club is moving before it collides with the ball and the ball is motionless. But in baseball, the bat and the ball are typically *both* moving before a collision between them.

With your class

1. In each collision, what is doing the pushing and what is getting pushed?



Exploring Force Interactions with Fingers

With your class



2. Begin by holding your index fingers about a centimeter apart.
 - Do you feel any push between your fingers when they are not touching?
3. Slowly push your right fingertip into your left fingertip.
 - Do you feel a push on your left fingertip?
 - Do you feel a push on your right fingertip?
4. Repeat all the steps, but switch fingers. Slowly push your left fingertip into your right fingertip.
5. Repeat the previous steps with your eyes closed.
6. Do all of these steps with your eyes open, paying close attention to which fingertip's surface deforms.
7. Slowly push your right fingertip into your left fingertip. Look for deformation of each fingertip.
 - Do you see the surface of your left fingertip deform?
 - Do you see the surface of your right fingertip deform?
8. Repeat the last steps, but switch fingers. Slowly push your left fingertip into your right fingertip.
9. Now repeat all the steps, pushing one fingertip against another a little harder.
 - How does that affect the amount of deformation you see on each fingertip?

Making Predictions

On your own



10. Use *Comparing Forces on Two Push-Pull Spring Scales* that your teacher will hand out to make predictions about the forces you will observe in each of the different scenarios.

With your group



11. After everyone in your group has recorded their predictions, get 2 spring scales for your group and zero both of them. Also pick up 1 S hook.
12. Two group members should each hold a spring scale and test the push interactions described on the handout. Everyone should record results.
13. Assign two different group members to each hold a spring scale, connected with an S hook, and test the pull interactions described on your handout. Everyone should record results.
14. Discuss the following:
 - In every case, how does the strength of the forces on each object compare?
15. Be ready to share with the class.

Making Sense of the Results and Testing Force Interactions Between Different-Stiffness Springs

With your group



16. The spring in the scale on the right is stiffer than the spring on the scale on the left. The one on the right stretches half as far as the one on the left for the same amount of force pulling on it.
 - Discuss predictions with your group:
 - How will the forces on each spring scale compare when you push them against each other?

Planning Our Next Investigation

With your class



17. Discuss as a class:
 - What are some different collision conditions that we could possibly test with these carts?

On your own



18. Record the question your group will be investigating on *Lesson 5: Independent, Dependent, and Controlled Variables* that your teacher will hand out.
19. Tape the handout into your notebook.



- 20.** For home learning, read *Reading: How does touch work?* that your teacher will pass out.

Navigation

With your class



- 21.** Discuss with your class:

- What are different groups investigating?
- How do you predict changing this variable will affect the forces on both objects in your collisions?
- How is investigating this variable connected to the ideas we have developed so far about why things sometimes get damaged when they hit each other?

Introducing a Way to Measure Peak Force

With your class



- 22.** Watch the demonstration video your teacher will show.

- 23.** Discuss the following questions:

- What happened to the twist tie collar in the collision?
- How can this twist tie help us measure the maximum amount of force (peak force in a collision)?

Investigating Peak Forces

With your group



- 24.** Review materials you have available.

- Discuss with your group and record on your handout the variables for your investigation.
- On the next page of your notebook, set up a data table to record your results as well as a space to make note of any challenges or any sources of error you notice in your investigation.
- Everyone in the group should have this, and goggles ready to put on, before going over to the lab area to carry out your investigation.

Update Progress Tracker.

In your notebook



- 25.** Add to your Progress Tracker. Record the question we are trying to figure out:

- How does changing the mass or speed of a moving object before it collides with another object affect the forces on those objects during the collision?
- Record what you figured out.

- 26.** Be ready to share with the whole class.

Develop a Consensus Model.

Scientists Circle



27. Meet in a Scientists Circle and develop a model to represent what you figured about this question:

- How does changing the mass or speed of a moving object before it collides with another object affect the forces on those objects during the collision?

Exit Ticket

On your own



28. Think back to one of your collision cases you shared with the class where two objects collided and one or both of them got damaged.

- Which object(s) had kinetic energy before the collision?
- How did the strength of the peak forces on each of these two objects compare during the collision? Were they equal in strength or unequal in strength?
- If one of your moving objects was moving slower before the collision, how would that have affected its kinetic energy?
- How would that have affected the peak forces in the collision?

Lesson 6: What have we figured out about objects interacting in collisions? How can we apply our new learning to answer questions about objects interacting in collisions?

Navigation

With your class



1. Last class we learned a lot about peak forces in a collision. We learned that they are equal on both objects, but applied in opposite directions. We have also figured out a lot of other ideas along the way. Let's look back at what we have learned so far in this unit.
 - Turn to your Progress Tracker and help your class make a list of what we have learned so far.
 - Your teacher will record your ideas on a poster titled "What We Have Discovered".

Revisit the Driving Question Board.

With a partner



Let's take a look back and see if we can apply any of these ideas to answer questions on our Driving Question Board (DQB).

2. Look over the list of DQB questions with your partner.
3. Using *Reviewing Our Driving Question Board*, identify some questions we have made progress on. Identify another question you think you can now answer. Answer the question in the bottom space, using evidence from past activities to support your answer.
4. After we have had a chance to work on these questions, we will come back as a whole class and share what questions we can now answer.

Checking on Our Progress

With your class



5. Discuss the questions below with your class:
 - Can you now answer a question that we could not answer at the beginning of the unit?
 - What questions do you now feel comfortable answering? What were your answers?
 - Were there any questions about mass and speed that we couldn't answer yet? Which ones?

Checking Our Understanding

Let's see if we can apply our learning to a new phenomenon! There have been discussions in soccer that headers should be banned because the collision can be dangerous. Use our science ideas to figure out if a header can actually cause a concussion and determine if there are other collisions that occur in soccer that can cause concussions as well.

On your own



6. Write your name on *Soccer Assessment*. Listen as your class goes over each question.
 - Questions 6–7 will help us figure out where to go next. Do your very best to explain your reasoning.
 - We will come back together to discuss our ideas about mass and speed at the end of class. Be ready to share your ideas.

Discussing Mass and Speed

With your class



7. Share your thoughts with the class about question 6 on the assessment.
8. What do we already know happens to the kinetic energy of a moving object when we increase its mass or its speed?
 - What do you think is a bigger factor contributing to damage in any collision: the speeds of the objects involved in the collision or the mass of the objects involved in the collision, and why?
 - Next class period we will have to try to figure out what has more of an impact on the kinetic energy and peak forces in a collision—mass or speed increases!

Lesson 7: How much does doubling the speed or doubling the mass affect the kinetic energy of an object and the resulting damage that it can do in a collision?

Navigation

With your class



1. Discuss the following questions with your class:
 - How does increasing either the speed or mass of a moving object affect its kinetic energy?
 - How do such changes affect the peak forces in a collision between that moving object and a stationary object?
 - How would such changes affect the amount of damage done in a collision?

Identifying Variables

With your class



2. Identify what variables we will need to change in an investigation that answers the question: How much does doubling the speed or doubling the mass affect the kinetic energy of an object and the resulting damage that it can do in a collision?

Preparing for Investigation 1

On your own



3. Add handout *Changes in Kinetic Energy: Investigations #1 & 2* to your notebook.
4. Review the procedure on *Procedure for Investigation 1* before carrying out the investigation.

Carrying Out Investigation 1

With your group



5. Carry out investigation 1 using the procedure on *Procedure for Investigation 1*.

Recording Data from Investigation 2

On your own



6. Watch condition A and record the related data in your investigation 2 data table.

Make predictions.

Turn and talk



7. Discuss your predictions:

- When we double only the mass of the cart, how much further will it push the box?
- When we double only the speed of the cart, how much further will it push the box?

Recording Data from Investigation 2

On your own



8. Watch conditions B and C and record the related data in your investigation 2 data table.

Analyzing Results and Making Predictions

With a partner



9. Answer the following questions:

- About how many times further did the box get pushed when the mass was doubled?
- About how many times further did the box get pushed when the speed was doubled?
- What does this tell us then about how much more kinetic energy the cart had in each case?
- Based on these patterns, make a new set of predictions:
 - If you tripled only the mass of the cart, how many times further will it push the box?
 - If you tripled only the speed of the cart, how many times further will it push the box?

Sharing Results and Predictions

With your class



10. Discuss the following questions with your class:

- About how many times further did the box get pushed when the mass was doubled?
- About how many times further did the box get pushed when the speed was doubled?
- What does this tell us then about how much more kinetic energy the cart had in each case?

- Based on these patterns, make a new set of predictions:
 - If you tripled only the mass of the cart, how many times further will it push the box?
 - If you tripled only the speed of the cart, how many times further will it push the box?

Preparing for Investigation 3

With your class



In your notebook



11. Orient to the simulation you will be using as a class.

12. Title a new page in your notebook: *What is the relationship between change in the mass or the speed of a moving object and its kinetic energy?*

13. Set up two data tables in your notebook:

Mass of the moving object for a fixed speed	Kinetic energy of the cart (measured as the distance the box is pushed)

Speed of moving object for a fixed mass	Kinetic energy of the cart (measured as the distance the box is pushed)

Carrying Out Investigation 3

On your own



14. Use the simulation to carry out your investigation. (<https://www.openscienced.org/collision2-simulation/>)
15. Record your results in your data tables.
16. Create a coordinate graph for each of your data tables:
 - Title both of your graphs.
 - Label your axes and intervals.
 - Plot your data as coordinate points

Analyzing and Interpreting the Results of Our Investigations

With a partner



17. Discuss the following questions with your partner:
 - What patterns do you notice in your graphs and tables?
 - Use these patterns to calculate how much the kinetic energy of a moving object should increase if
 - it had **three** times as much **mass**, but the same speed.
 - it had **three** times as much **speed**, but the same mass.
 - In math you sometimes try to represent patterns between two variables using symbolic expressions. How might we do that for the following relationships?
 - mass and kinetic energy
 - speed and kinetic energy

Applying Our Ideas

Writing in Science



18. Reflect on what we figured out across the three investigations and how this helps us predict and explain why things sometimes get damaged when they hit each other and sometimes they do not.
19. At the end of the period, turn in your responses to the questions on your *Looking back* handout along with the two graphs you made from your investigations.

Navigation

Turn and talk



20. Discuss the following questions with your partner.
 - Where did all the kinetic energy the cart had before the collision come from?
 - After the collision, where did that energy go?
 - What new questions does this raise for you?

Lesson 8: Where did the energy in our launcher system come from, and after the collisions where did it go to?

Navigation

With your class



1. At the end of the last class, we started considering energy transfer in the cart, track, and box system in order to better understand what is happening in that system. Discuss this question with your class: What new questions did thinking about energy transfer into and through the entire system raise for you?

Developing Individual Models

On your own



2. Use your handout *Tracking energy transfers in our launcher system* to think about where energy transfers may be occurring in different subsystems and in smaller windows of time before, during, and after the cart launch.

Develop a Consensus Model.

Scientists Circle



3. Bring colored pencils and meet in a Scientists Circle to develop a model showing how energy was transferred and where contact forces were occurring in the launcher, cart, box, and track system.

Develop individual models.

On your own



4. Refer to the annotations we made to the systems model and consider what else might be going on at time 4.
 - First think about forces in the system at this point in time as you develop and use free-body diagrams in your responses to the first 3 questions on your handout *Modeling other force interactions in the launcher, cart, box, and track system*.
 - Then think about energy transfer in the system at this point in time in your responses to the last question on your handout *Modeling other force interactions in the launcher, cart, box, and track system*.

Investigations into Air Resistance and Friction

Home Learning



5. Choose one (or both) of these investigations to carry out and report on.
 - Folding and dropping paper: *An air interaction investigation*
 - Take 4 index cards (provided) and complete the related handout.
 - Pulling a shoe with a rubber band: *A surface interaction investigation*
 - Take a rubber band (provided) and complete the related handout.

Lesson 9: How do other contact forces from interactions with the air and the track cause energy transfers in the launcher system?

Sharing Results from Our Home Learning Investigations

With your group



1. Pair up so that there is one person with results from each investigation. Have each person share responses to the last two questions on the handouts *Investigating Surface Interactions* and *Investigating Interactions with the Air*.

Navigation

With your class



2. Discuss this question with your class: What ideas do you have from the home learning that could help explain where other contact forces in the system may be causing the box to slow down and eventually stop?

Conducting Investigations: Other Forces in Our Collision System

With your group



3. Use the procedures and materials provided at each station to collect and record observations on your handout *Data collection from stations*.

Construct an argument from evidence.

On your own



4. Construct an explanation to answer this question:

How do other contact forces, like friction and air resistance, cause energy to be transferred between a moving object and other parts of a system?

Include answers to these questions:

- What causes these forces?
- How do these forces transfer energy in the system?
- What evidence from your assigned station investigation supports your explanation?

Navigation

On your own



5. Reread your explanation you made last time to answer this question: ***How do other contact forces, like friction and air resistance, cause energy to be transferred between a moving object and other parts of a system?***

Prepare to share this explanation with others by highlighting or underlining the ideas you want to emphasize and that are important to add to our model.

Review our norms.

With your class



6. Revisit the classroom norms and share ideas for which norms are especially important when giving and receiving feedback.

Jigsaw Feedback Group Discussion

With your group



7. Take turns sharing and defending your explanation with your group members. Use the discussion questions on your handout *Jigsaw feedback discussion* to identify important ideas to add to our model.

Revising Our Cart-Launcher System Model

Scientists Circle



8. Work as a class to revise your model based on our ideas about how other contact forces, like friction and air resistance, cause energy to be transferred between a moving object and other parts of a system. Use colored pencils to add annotations to *Energy transfers and contact forces in the launcher, cart, track, and box system* to reflect these new ideas.

Update our Progress Trackers.

In your notebook



9. Create an entry in the Progress Tracker section of your notebook and record our lesson question and what we have figured out.

Question	Source of evidence
How do other contact forces, like friction and air resistance, cause energy to be transferred between a moving object and other parts of a system?	
What I figured out in words and pictures	

Revising Your Individual Model

Home Learning



10. Review the model and explanation you developed before this lesson for what you thought was going on at time 4 on *Modeling other force interactions in the launcher, cart, box, and track system*. Use a new color to modify this model and explanation so that it represents your new thinking based on what you figured out in this lesson.

Lesson 10: Why do some objects break or not break in a collision?

Navigation

With your class



1. Discuss the following with your class:
 - We have learned a lot about what can affect the motion of objects and how those objects interact in a collision to cause damage or no damage. Let's take stock of what we have learned and record it on our Big Ideas poster.

Revisit and explain collision types.

With your class



2. Recall the 3 main types of collisions we have categorized:
 - Collision type A: A moving object was damaged OR was not damaged when it collided with a motionless object.
 - Collision type B: A motionless object was damaged OR was not damaged when a moving object collided with it.
 - Collision type C: A moving object was damaged OR was not damaged when it collided with another moving object.
3. Do you think we can better explain why some objects broke in those collisions and others did not?

Explaining Different Types of Collisions

With your group



4. Follow your teacher's directions and use handout *Explaining a Collision* to investigate collision types with your group.

Partner Feedback

With a partner



5. Work with someone who has **the same** collision type as you. Share both of your ideas on question 3, then give feedback using the following questions:
 - What is similar about your boxes? What is different?
 - Do you agree or disagree on the factors that could change the outcome of a collision in box 3?
 - What changes would you suggest based upon your partner's model?

6. Work with someone who has a **different** collision type as you. Share both of your ideas on question 3, then answer the following questions with your partner:
- What is similar about your boxes? What is different?
 - Do the differences make sense based upon your different collision types? Why or why not?
 - Do you see anything in your partner's boxes that you would like to add to your boxes?
 - What changes would you suggest based upon your partner's boxes?

Revisit the DQB.

With a partner



7. Discuss the following questions with a partner:
- What areas of the DQB have we made progress on?
 - Are there any specific questions that we can now answer that we could not answer last time?

Lesson 10 Assessment

On your own



8. We have learned a lot about damage and collisions. Let's see if we can apply our new learning to a baseball scenario! Follow your teacher's instructions to complete the Lesson 10 assessment.
- Do your best to answer the questions on the assessment.
 - When you are done, turn in the Lesson 10 assessment to your teacher.

Lesson 11: What can we design to better protect objects in a collision?

Look back at phone case data.

Looking back at the data, even with cases, 27% of phones were still getting broken! The cases seem to help, but they do not completely eliminate damage.

With your class



1. Discuss the following questions with your class:

- If there is still damage when a phone is in a case, why do people even use them?
- What would you think people would say is the primary purpose of a phone case?
- What could make that case better at meeting its purpose?
- What other things could make the case a better case?

Consider phone case criteria and constraints.

Remember from the *Homemade Heater Unit*, *Cup Design Unit*, and *Tsunami Unit*, *criteria* are the things a device needs to have or do to meet its main goal or purpose. *Constraints* are other considerations and limits from people or the environment.

On your own



2. Discuss the following questions with your class:

- What criteria would a phone case need to have to better meet the purpose of protecting the phone?
- What are some stakeholder considerations we should have? Is there anything that would limit our designs?

Consider other objects that need protection.

Turn and talk



3. Turn and talk with a partner about the following questions:

- What are some objects that need (better) protection in a collision?
- What general ideas do you have to make it (better) protected from damage?

Be ready to share your ideas with the class.

4. Turn and talk with your partner about the following questions:

- If you had to pick only one object that you interact with a lot that you would want to protect from damage, what would you pick, and why?
- If we were to make a protection device for this object, what damage-reducing solutions could you come up with?

Be ready to share your ideas with the class.

Draft a plan for protecting a new object.

With your class



5. Write your name on the top of *Protection Device Design Thinking*.
6. Listen for directions from your teacher as we go over *Protection Device Design Thinking* as a class.

On your own



7. Complete *Protection Device Design Thinking* on your own.
Be ready to share with the class the criteria and constraints you have identified for your device.

Share designs with a partner.

In order to make a better protection device, the device cannot just be what the designer wants it to be. It also has to meet the needs of the many people who might want to buy it. Because of this, it is important to get feedback from others.

With a partner



8. Give and receive feedback on a design.
 - Each person will have 4 minutes to explain their design and receive feedback.
 - Partner #1 will explain their device to partner #2.
 - Partner #2 will then give feedback to partner #1 until the timer goes off.As you are giving feedback, focus on these key questions to help give good feedback to your partner:
 - What do you like about the design?
 - What changes would make it “better” at protecting the object?
 - What other changes would you make for this design to be more appealing to a stakeholder?

Home Learning

Home Learning



9. Take home your design and revise it based on the feedback they give you.
Be ready to share what feedback you received and any changes you have made. Next class we will do a gallery walk of our designs.

Share home learning with a partner.

With a partner



10. Get out your design ideas from last time. Turn to a partner and tell them what feedback you received from family and friends.
11. Look back at your designs. Put a checkmark (✓) or star next to any design changes you made after you left last class.

Gallery Walk

With your class



12. During our gallery walk, we will be giving feedback that is specific and actionable that can be used to improve designs. As you are conducting your gallery walk, answer these feedback questions to give feedback on designs:

- What **changes** would make it “better” at protecting the object?
- What other changes would you make about the way it **looks**, the **material**, or the **shape** that would make you more likely to want to use it more?
- What parts do you think will **function well**?

Follow these instructions for the gallery walk:

- Leave feedback on at least 3 different designs. Leave only 1 sticky note per design.
- Use all 3 feedback questions during your feedback process.
- If you come to a design with 3 sticky notes already on it, move on until all designs have at least 3 sticky notes.

Compare criteria and constraints.

With a partner



13. Work with a partner to compare your feedback. Use the following questions to guide your conversation:

- What do your feedback and designs seem to have in common?
- Do your designs have similar criteria and constraints? If so, what are they?
- Do you have any feedback that is not similar to your partner’s feedback?

Turn and talk



14. Turn and talk with a partner about the following question:

- If we were to make a criteria and constraints list that would work for all our designs, what would be on the list?

Be ready to share your ideas with the class.

Develop questions and ideas for investigations.

Scientists Circle



15. Meet your class in the Scientists Circle with your notebook and a pencil.

16. Look back at

- the class-created charts
- your design handouts
- your design feedback

What questions do you now have about the **materials, design, structure, and function** of these protection devices?

17. Record at least 2 questions on separate sticky notes that your teacher has given you.
18. Write at least 1 idea for investigation on a separate sticky note.

Share questions and ideas for investigations.

Scientists Circle



19. Let's share our questions and ideas for investigations as a class.

- One by one, we will go around and share one question and idea for investigation.
- As the first person reads their question and idea for investigation, give a thumbs up if you wrote down the same question or the same idea for investigation.
- The person reading the question and the idea will collect the sticky notes with the same question and the same idea for investigation from people with their thumbs up and layer them on top of each other.
- The reader will then post them on our T-chart in the appropriate column.
- After this, the next person in the circle will read a question and an idea for investigation until all relevant questions and ideas are on the board.

Next Steps

Turn and talk



20. Turn and talk to a partner about the following question:

- If we are going to design a protection device, what is something that we all need to investigate to build a better device?

Be ready to share your ideas with the class.

Lesson 12: What materials best reduce the peak forces in a collision?

Navigation

With your class



1. Discuss the following questions with your class:
 - What does it mean to use good materials that are protective? What would those materials do?
 - How do you think those materials function?
 - How do we think those materials help reduce peak force or energy transfer to the object we are trying to protect?

Determine investigation setup.

Turn and talk



2. Discuss the following question with a partner:
 - How have we measured peak force in the past that we could reuse or repurpose for our investigation today?

Predicted Material Performance

In your notebook



3. Follow your teacher's directions to make a chart in your notebook and complete the following:
 - Make a prediction about how the materials will perform in our tests compared to no material at all.
 - Create in your notebook the chart shown on the slide.
 - Next, rate the materials on their predicted performance during a collision.
 - + if peak forces will **increase**
 - – if peak forces will **decrease**
 - = if peak forces will **remain the same**
 - Circle the material you think will reduce peak forces **the most** in a collision.

Comparing Ideas

Turn and talk



4. Discuss the following questions with a partner:
 - What material do you think will **reduce** peak force the most? Why?
 - What material(s) do you think will perform the **worst**? Why?

With your class



5. Your teacher will read off the list of materials. Raise your hand if you think that material will **best** reduce peak forces.
6. Your teacher will read the list a second time. This time, raise your hand if you think the material will perform the **worst** at reducing peak forces.

Testing Materials

With your class



7. Discuss the following questions with your class:
 - Where would we have to place the material so that we could see if it reduces the peak forces on our colliding objects?
 - How can we secure the test materials in place when we are running our tests?

Create accurate readings.

With your group



8. Work with your group and follow these directions to calibrate the spring scales so we can accurately compare the potential force reduction data from our materials testing:
 - Check your spring scales. Do they show 0 newtons when held on their sides?
 - Push in and out on the spring scale rod a couple of times and make sure that it rests at 0 newtons.
 - If it is not at 0, use the white screw on the end to adjust the scale. Once you have it set, push in on the rod and let go to check that it rests at 0 newtons.

Materials Testing

With your group



9. Use handout *Cushioning Materials Testing Procedures* and follow your teacher's directions to conduct materials tests.
 - Use your lab setup to run tests both *with* and *without* the potential protective material in your collision.
 - Follow the directions on your *Cushioning Materials Testing Procedures* and make sure to record your data as you go.
 - If your data have a large range, first check that your force collar is not loose. After data collection, if one trial is ± 0.2 N more than the mean (average), redo that trial.
 - Once you are done, subtract the peak force average *with* a protective device from the control peak force average.
 - Record your results on the class chart.

Analyzing Results

In your notebook



10. Look back at the class data from our lab and answer the following questions in your notebook:

- What materials seemed to do the best at reducing peak force on the nonmoving object?
- What patterns in material structure do you see in these “top performers”?
- Think about the materials. What special features or properties of the material’s structure would make it function better than a worse-performing material?
- How do you think the structures of the materials behave in a collision that would reduce the peak forces on the objects?
- Was the peak force reduced on both objects or just the nonmoving object?

Reviewing Class Data

Turn and talk



11. Discuss the following questions with a partner:

- What materials were our “top performers” or seemed to work best to reduce peak force on the nonmoving object?
- What patterns in material structure did you see in the “top performers”?
- Did the material reduce the peak force on both objects or just on the object that was nonmoving?

Comparing Spring Scale Measurements in Small Groups

With your group



12. Follow your teacher’s directions and conduct the following with your small group:

- Use two different spring scales to push in on each other. How do the readings compare?
- Place a protective material between the two spring scales. How do the readings compare?
- Swap scales with another group to get a different type of scale and try both of these again. Are the outcomes the same or different?

Whole-Class Share

With your class



13. Discuss the following questions with your class:

- As you pushed in on each scale, what did you notice happening to the protective material?
- What did you notice about the readings on each scale?
- What felt different about pushing the scales with and without the protective materials between them?

Material Structure

Turn and talk



14. Discuss the following question with a partner:

- Look at the zoomed-in images of some of the materials we tested. What do you notice about their structures?

Comparing Ideas

With a partner



15. Complete the following with a partner:

- Look back at your ideas you wrote in your notebooks about what specific features of the materials may be causing a reduction in peak forces.
- Compare your ideas with a partner. You can use this time to revise or update your ideas if needed.

Constructing Explanations

On your own



16. Use *How can materials reduce peak force on the objects they protect?* to try to explain what happens to the protective material as a contact force is applied.

Lesson 13: How (and why) does the structure of a cushioning material affect the peak forces produced in a collision?

Navigation

With your class



1. Discuss this question with your class: What structures did the materials seem to have in common that were good at reducing peak forces?

Develop and use a model.

Scientists Circle



2. Meet in the Scientists Circle to develop a consensus model that represents the general structures we all agree are a part of the materials we examined up close and at a microscopic level and describe why we think they behave in similar ways.

Predicted Material Performance

Turn and talk



3. Discuss the following questions with a partner:
 - Would adding ring structures to the system, as shown in B and C, affect the peak forces in the collision? Why or why not?
 - Would attaching these structures to the stationary object (brick), as shown in D and E, instead of to the moving object affect the peak forces in a collision? Why or why not?

Record and analyze data from slow-motion videos.

With your class



4. Do the following activity as a class:
 - Watch videos A and B and record your observations on your handout *Observations from Adding Additional Ring Structures*.
 - Discuss what you notice from these videos.
 - View videos A and B again and record any additional observations.
 - View videos C, D, and E and record your observations.

Analyze and interpret our data.

With your class



5. Discuss the following questions with your class:
 - What patterns did you notice in the peak forces produced?
 - What patterns did you notice in the time these collisions took?

Update Progress Tracker.

Writing in Science



6. In your Progress Tracker, record the question we are trying to figure out: *How (and why) does the structure of a cushioning material affect the peak forces produced in a collision?*
7. Record what you figured out and be prepared to share your thinking with the whole class.

Develop a Classroom Consensus Model.

Scientists Circle



8. Let's meet in the Scientists Circle and develop a series of free-body diagrams to represent what you figured out about this question: *How (and why) does the structure of a cushioning material affect the peak forces produced in a collision?*

Develop and use a model.

Writing in Science



9. Using *Free body diagrams for collisions with and without cushioning structures*, add a diagram to the last row of your table showing the objects and subsystems that would be involved in a collision that had a series of rings connected together on either the brick or the cart.
10. Create a series of free-body diagrams to show how the relative strength of the peak forces on each subsystem in this collision would compare to the other conditions.
11. Which collision would occur over the longest contact time? Put a star next to that row of your table and label it.

Predict the effects of other structural changes.

Turn and talk



12. Discuss the following questions with a partner:
 - If we wanted to double the number of air gaps or spaces in the structure of a cushioning material, how would the size of those air gaps or spaces have to change in order to fit them in?
 - Do you think that change would also affect the reduction in peak forces than those structures provided in a collision?

Analyze size data and update Progress Tracker.

With a partner



13. Analyze the data shown on the slide.
14. Add to your Progress Tracker under the entry for the same question you added for your previous discoveries: *How (and why) does the structure of a cushioning material affect the peak forces produced in a collision?*

Navigation

Turn and talk



- 15.** Discuss this question with a partner: Do you think other changes to the structure or shape of a cushioning material would affect how much it reduces peak forces in a collision? Why or why not?

Navigation

With your class



- 16.** Discuss this question with your class: Do you think other changes to the structure or shape of a cushioning material would affect how much it reduces peak forces in a collision? Why or why not?

Make predictions and test structures.

Writing in Science



- 17.** Add handout *Exploring shape of a cushioning material* to your notebook.

- 18.** Record your predictions for how each structure will respond.

With your class



- 19.** Follow your teacher's instructions and work with your class to test the structures.

Develop a Classroom Consensus Model.

Scientists Circle



- 20.** Prepare a new three-section tracker in your Progress Tracker.

- 21.** Meet in the Scientists Circle to summarize what you figured out as a class for your lesson question across all investigations.

Prepare to apply these ideas to your design.

Turn and talk



- 22.** Discuss the following questions with a partner:

- How could these ideas be applied to the design of a protective headgear for preventing concussions in sports-related collisions?
- How might you apply what we figured out to your design problem?

Design protective headgear.

Home Learning



- 23.** Complete the questions in the reading and prepare to turn it in at our next meeting.

Lesson 14: How can we use our science ideas and other societal wants and needs to refine our designs?

Recall what we know about cushioning materials.

With a partner



1. Turn and talk with a partner about this question:

- What did we learn about the shape, thickness, or properties of protective materials we should be using in our designs?

Be prepared to share your ideas with the class.

Revise designs.

On your own



2. We have learned a lot about the properties and structures of protective materials. Let's see if we can apply these ideas to optimize our designs.

- Get out *Drafting Our Protection Device Design* from Lesson 11.
- We will use this design as a starting point as we redraft our designs on *Redesigning Your Protective Device*.
- After that, we will have the opportunity to think about the specific changes we are proposing and why we are making those changes.

Update criteria and revisit constraints.

With your class



3. Discuss the following question with your class:

- Other than our criteria, what else did we say we needed to consider as a class?

Discuss trade-offs with knee pads.

With a partner



4. Turn and talk with a partner about the following questions:

- What are some constraints that would apply to this protective device?
- Are there any constraints that the design would have that are more important than others?

Be ready to share your ideas with the class.

With your class



5. Discuss the following question with your class:

- Looking at the knee pad device, what do you think are some criteria and constraints that would apply to this device, both from a science idea perspective and the perspective of someone who is going to use it?

With a partner



6. Turn and talk with a partner about the following questions:
 - If we were to think about trade-offs for our devices, who would we need to consult to be sure we were making an informed decision about what was important?
 - Why would we need to consult and consider the feedback of others in the first place?

Be ready to share your ideas with the class.

Home Learning

We have a form to use that will help us get feedback from stakeholders. The form is set up to ask the stakeholder questions based upon the design type and will get targeted feedback to help optimize your design.

With your class



7. Look at *Stakeholder Feedback Form* with your class. Listen carefully as your teacher goes over the different steps.

Home Learning



8. Take home both *Redesigning Your Protective Device* and *Stakeholder Feedback Form* to get feedback from your stakeholders. Remember, stakeholders can be other teachers, students, neighbors, friends, or even siblings or other family members.

Share feedback from home learning.

With your class



9. Share your feedback with a partner. Use the questions below to help guide your discussion.
 - What trade-offs or ideas did your stakeholder give you?
 - What feedback are you considering and not considering for the redesign of your device? Why?

Utilize a decision matrix to evaluate materials.

With your class



10. Look at *Decision Matrix* with your class.
 - On this matrix we will use the 1-to-5 scale to rate how well each material meets the considerations of the stakeholders.
 - A rating of 5 is the best.
 - A rating of 1 is the worst.
 - Look back at your design and identify potential materials you would like to use. Write these materials in the spaces in the “Material choice” column.

- Think about your stakeholder considerations. List these considerations in the red space in the “Considerations” heads, just as you did in past units.

We have some materials data from the Michigan State University School of Packaging. MSU used a Life Cycle Analysis (LCA) program to assess our materials from Lesson 11. They also used research data to compile additional categories.

With your class



11. Look at the column heads. Here are what the categories mean:

- Force reduction- how well the material reduces force on an object that it is protecting (The better the score is, the better the device does at reducing peak forces.)
- Reusable- It can collide with other objects again and again and still be reused.
- Robust- how well the device will work to protect heavy objects in a collision
- Recyclable- how easy it is to recycle the material based upon availability of recycling sites for that material
- Biodegradable- how well the material will biodegrade when thrown out
- Low material cost- how cheap the material is for the same size sample
- Low cost to work with the material in a design- how inexpensive it is to pay a worker to use that material to create a design solution
- Water used for production- how much water goes into the creation of that material
- Does not contribute to climate change- how small of an impact the creation of the material has on climate change

12. Copy any relevant considerations that you would like to use from this list onto your own matrix.

With a partner



13. Look at your chosen considerations for each material.

- Spend some time transferring over the consideration ratings from the MSU matrix to your matrix for those materials.
- If the material or consideration does not exist on the MSU sheet, think about how the material would meet the considerations *compared* to the current analyzed rankings.
- If you have to create your own rating, ask a partner to check your newly developed rating to see that it makes sense compared to the other materials and considerations.

Using Data to Analyze Material Choices

With a partner



14. Turn and talk with a partner about the following questions:

- Use your "Total points" column to total up the ratings for the materials in your particular design.
- If we were to look at the ratings and select the best material based upon which material has the highest overall rating, would that be the best material for the design? Why or why not?

With your class



15. Discuss the following question with your class:

- If we were to establish a consideration across all designs that was the most important, what would it be?

On your own



16. Use the rankings below to help guide you as you classify your considerations as **primary**, **secondary**, or **tertiary**. Write "P", "S", or "T" above each "Consideration" column.

- **Primary considerations**- the most important considerations for our designs
- **Secondary considerations**- the considerations that are still important, but we have more flexibility meeting
- **Tertiary considerations**- the considerations that are the least important to the overall design but may still be seen as important to some stakeholders

With a partner



17. When engineers and other scientists have to rate objects or data, they call the process *establishing interrater reliability*. Let's engage as scientists in checking our ratings with a partner.

- Follow the guidance below as you work with your partner to assess interrater reliability.
 - Have a partner look at your ratings and see if they agree with them. If they agree, keep the rating the same. If they do not agree, discuss why each of you would give a different rating. If needed, ask a third person to weigh in. Try to come to a consensus.
 - Give your partner feedback on any changes you would make to their ratings with your reasoning.

With your class



18. Discuss the following question with your class:

- Let's look back at our materials. We have ranked them as primary, secondary, and tertiary. But if we add up the total values, does the overall score change?

On your own



19. Adjust scores to reflect ratings.

- Look at your scores and multiply them based upon your ratings of primary, secondary, and tertiary.
 - Primary considerations- multiply the rating by 3
 - Secondary considerations- multiply the rating by 2
 - Tertiary considerations- rating stays the same
- Add up the ratings for each material after you have done the multiplication.

With a partner



20. Look at the questions below and answer them with a partner:

- Look at your adjusted total scores. Do these scores seem to better reflect what stakeholders value?
- Do you think that these scores are more accurate? Why or why not?
- Do you feel that these new scores are more useful?

Consider consequences of trade-offs.

On your own



21. Record the chart below in your notebook. As you are filling out the chart think about the choices that have been made and how they affect stakeholders and the structure.

My material and design choices	Effects these changes have on other stakeholder considerations	Effects on structure and function of design

Lesson 15: How can we use what we figured out to evaluate another engineer's design?

Synthesis Task for Design Pitch

Use materials from Lesson 14 to put together a design pitch for your design. The design pitch should explain why the final design is effective and should be made. In the pitch include the trade-offs you made and how you justify these trade-offs to the stakeholders.

Writing in Science



1. How would you explain the consequences of changing an aspect that the stakeholders were wanting in a design to something else, and how will this change benefit them and the design as compared to their original request?

Construct individual design pitch.

Writing in Science



2. Use all the work you have done and the resources you have to put together a written design pitch that includes
 - the purpose of your design (What will it protect?),
 - the material it will be made of and why, and
 - the trade-offs you made and why.

Part 1 Transfer Task

Writing in Science



3. Follow your teacher's directions to complete *Part 1: Cheerleading Headgear Assessment*.

Part 2 Transfer Task

Writing in Science



4. Follow your teacher's directions to complete *Part 2: Cheerleading Headgear Assessment*.

Revisit our Driving Question Board.

With your class



5. Add a green sticky dot to questions you feel you could fully answer and a yellow sticky dot for any questions you can partially answer.
6. Discuss the following questions with your class:
 - Which questions have we made the most progress on?
 - What have we figured out?

Reflect on our experience.

Writing in Science



7. Answer the following questions in your science notebook:
 - What was most challenging in this unit?
 - What was most rewarding?
 - Think about how you engage in sensemaking discussions with classmates. How would you want to engage in those experiences the next time around?
 - What would you do the same?
 - What would you do differently?

Investigation Procedures

1. Make sure you have recorded the material your group is testing above the data table on *Deformation Results*. 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 the amount of each end of the material overlapping the brick that the class agreed on. Tape down one end of the material to the brick surface.
4. Measure in centimeters the height of the center point of your object above the table. Record this in column B of row 1 and of row 2 of the data table on the *Deformation 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 in centimeters the height of the beam with the force applied to it. Have a third member record that height in row 2, column C and calculate the deformation in column D of the data table. In column A of row 2, write the force used, in this case "1".
6. Remove the force from the object. Record in column F whether the object returns to its original shape when the force was removed.
7. Repeat the last two steps for additional data points. Use different amounts of force than ones you already tested. However, reserve at least 2 measurements to repeat a previously tested amount. Remember to record the height before you apply the force in column B and the amount of force you apply in column A.
8. When you have the table complete, have other members of the group make a copy of the data in their own data tables.
9. Don't graph your data until instructed by your teacher.



Procedure for Investigation 1

Setting Up the System

1. Add your names to the top of 2 index cards. Label one "Condition B (doubling the mass)" and the other "Condition C (doubling the speed)".
2. Use two pea-sized pieces of sticky putty to secure two edges of a cracker to each index card. Make sure the putty is pushed flush against the cracker and isn't sticking out or above its face.



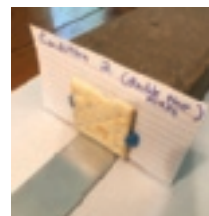
Calibrating the System for Condition A (original mass and speed)

3. Mass the cart and record its mass in your data table for investigation 1.
4. Place a brick at the end of the track. Use a piece of tape to mark on the table the location of the brick face so you can line up the brick at this same position later.
5. Hold the cart against the spring scale where it registers 5 N.
6. Release the cart and time how long it takes to reach the end of the track. Repeat this a few times to confirm that your data are relatively consistent.
7. Record how long it takes the cart subsystem to reach the brick. Calculate its average speed of travel in cm/sec.



Testing the System for Condition B (doubling only the mass)

8. Add mass to the cart using washers, paper clips, and a piece of sticky putty to secure them in place until the total mass of the cart is double what it was in condition A.
9. Hold the cart against the spring scale where it registers 7 N. This launch position should cause the heavier cart to travel at the same speed as in condition A.
10. Release the cart and time how long it takes to reach the end of the track to confirm that your data for its speed are relatively consistent and that the cart reaches the end of the track with the same speed as condition A.
11. Record how long it takes the cart subsystem to reach the end of the track. Calculate its average speed of travel to confirm it is now traveling at the same speed as condition A.
12. Slide a piece of paper under the end of the track and reposition the brick on top of the end of the track with a brick face perpendicular to the track where the piece of tape had marked its previous location.
13. Secure an index card and cracker against the brick face using one 2-cm-long piece of tape. The cracker should face the track and its bottom edge should be next to or on the track.



14. Launch the cart from the same launcher force position (7 N) as in step 10. The resulting collision with the cracker will damage it.
15. Carefully remove the index card from the brick. Remove the brick from the end of the track and slide the paper out from under it.
16. Place the index card and cracker on the paper. Brush all crumbs on the track on to the paper and then set aside the paper, index card, and cracker in a safe place in your work area so it will not be disturbed when testing the next condition.

Testing the System for Condition C (doubling only the speed)

17. Remove all the weights and sticky putty you added to the cart in condition B and remass the cart to confirm it has returned to the original mass it was in condition A.
18. Hold the cart against the spring scale where it registers 10 N. This launch position should cause the cart to travel down the track twice as fast as in condition A or condition B.
19. Release the cart and time how long it takes to reach the end of the track to confirm that your data for its speed are relatively consistent and that the cart reaches the end of the track with double the speed as condition A.
20. Slide a piece of paper under the end of the track and reposition the brick on top of the end of the track with a brick face perpendicular to the track where the piece of tape had marked its previous location.
21. Secure a new index card and cracker against the brick face using one 2-cm-long piece of tape. The cracker should face the track.
22. Launch the cart from the same launcher force position (10 N) as in step 19. The collision with the cracker will damage it.
23. Carefully remove the index card from the brick. Remove the brick from the end of the track and slide the paper out from under it.
24. Place the index card and cracker on the paper. Brush all crumbs on the track on to the paper and then set aside the paper, index card, and cracker in a safe place in your work area so it will not be disturbed when testing the next condition.



Pooling the Whole-Class Results and Analyzing the Results

25. Carefully transfer each paper and index card with the damaged cracker and debris on it to the area indicated by your teacher for pooling all the class results together.

Lab Station Instructions

Station 1 Instructions

1. Launch the cart without a notecard-sail attached down the track using the launcher. Reposition the fan in order to create wind conditions as follows:
 - a. No wind (fan off)
 - b. Headwind (fan in front of cart)
 - c. Tailwind (fan behind cart)
2. Try each of these conditions using the same amount of launcher force each time.
3. Notice how far the cart travels for each trial. Record your observations.
4. Locate the cart with a notecard-sail attached to the front of the cart with tape.
5. Hold the cart with the sail stationary with your hand and observe what happens to the shape of the sail when there is a fan blowing wind toward the front of the cart vs. toward the back of the cart.
6. Repeat steps 1 through 3 for conditions a, b, and c using the cart with a notecard-sail attached. Be sure to keep constant the launcher force you used when the cart had no sail.



Station 2 Instructions

Examine the data sets provided and record observations and insights you have about interactions between moving objects and air.

Station 3 Instructions

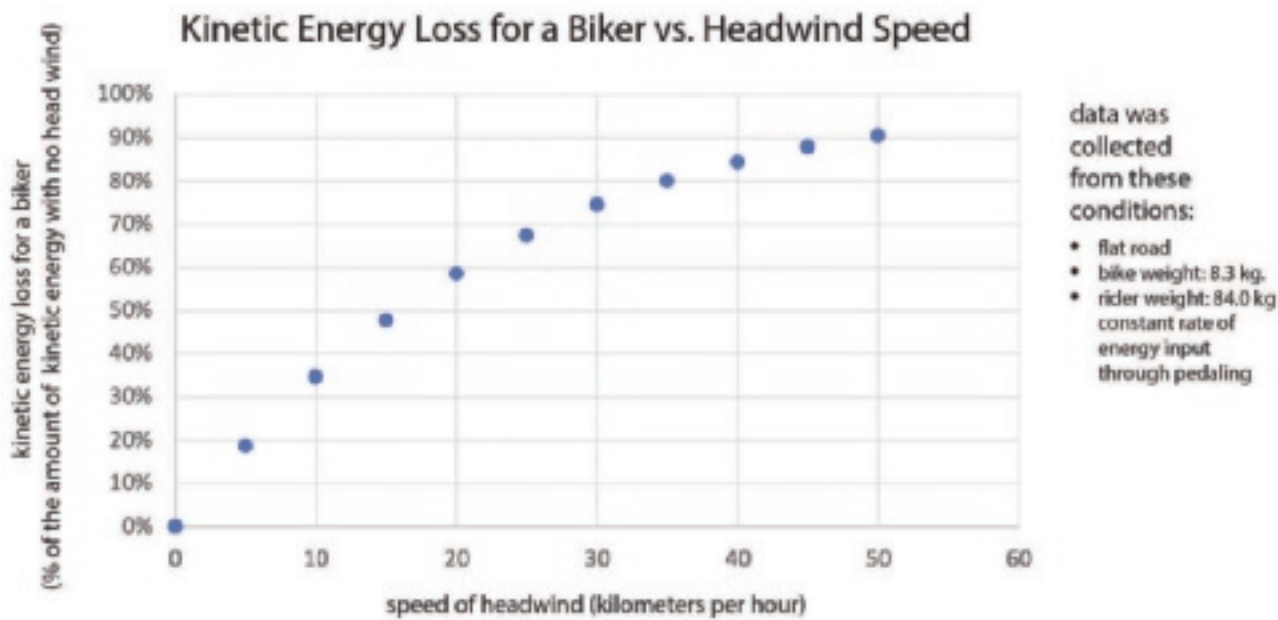
1. Point the infrared thermometer at the surface of the rubber eraser and measure the temperature.
2. Do this for the surface of the table too. Record these initial temperatures.
3. Produce friction between the surface of the rubber eraser and the surface of the table by rubbing the eraser back and forth quickly over a small spot on the table top for 10 seconds.
4. After doing this, use the infrared thermometer to measure the temperature of the surface of the table and the surface of the eraser again.
5. Record your observations.
6. Point the infrared thermometer at the surface of each of the pieces of Styrofoam provided.

7. Produce friction between the surfaces of the two pieces of Styrofoam by rubbing them together quickly for 10 seconds.
8. After doing this, use the infrared thermometer to measure the temperature of the surface of each piece of Styrofoam.
9. Record your observations.

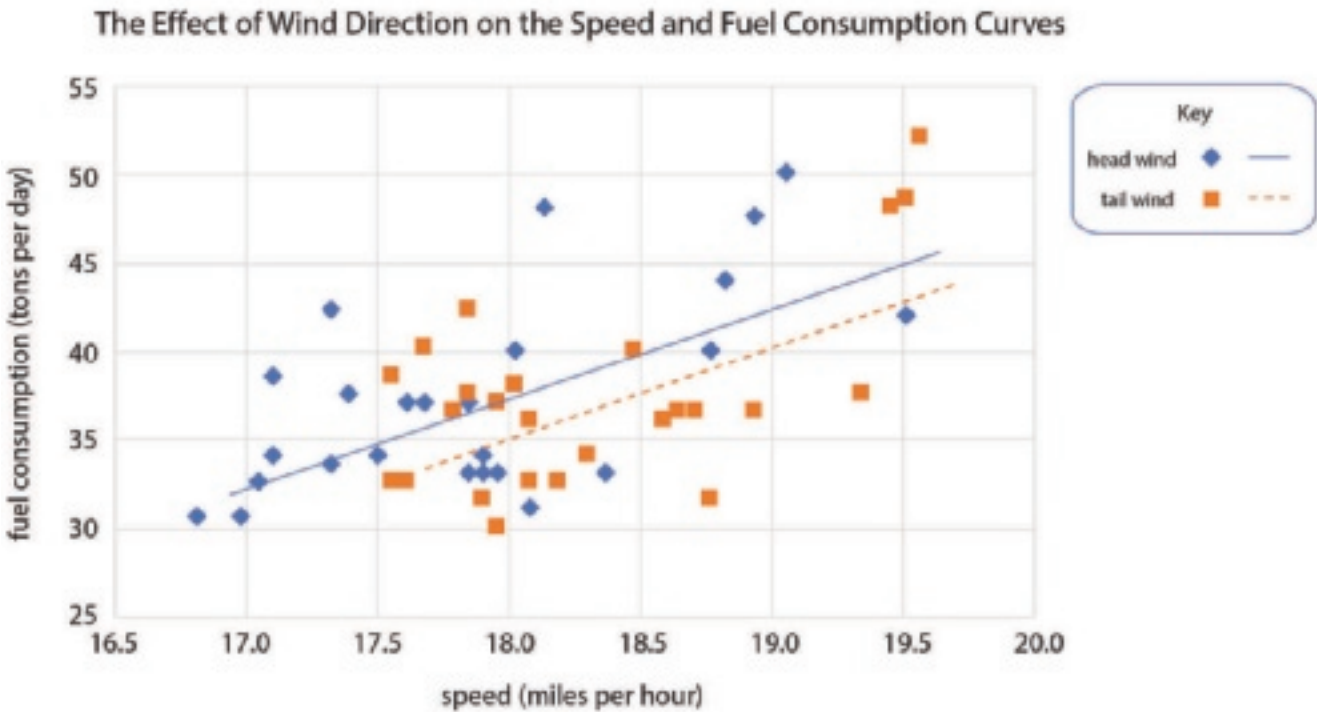
Station 4 Instructions

1. Examine the magnified images of different surfaces. What do you notice?
2. Record your observations.
3. Open the computer interactive (<https://www.openscienced.org/friction-simulation/>) showing the microscopic view of friction.
4. Press “play” and let the program run for several seconds. How does the motion of the objects and the particles that make up those objects change? You can reset and rewatch the simulation if needed.
5. Record your observations.

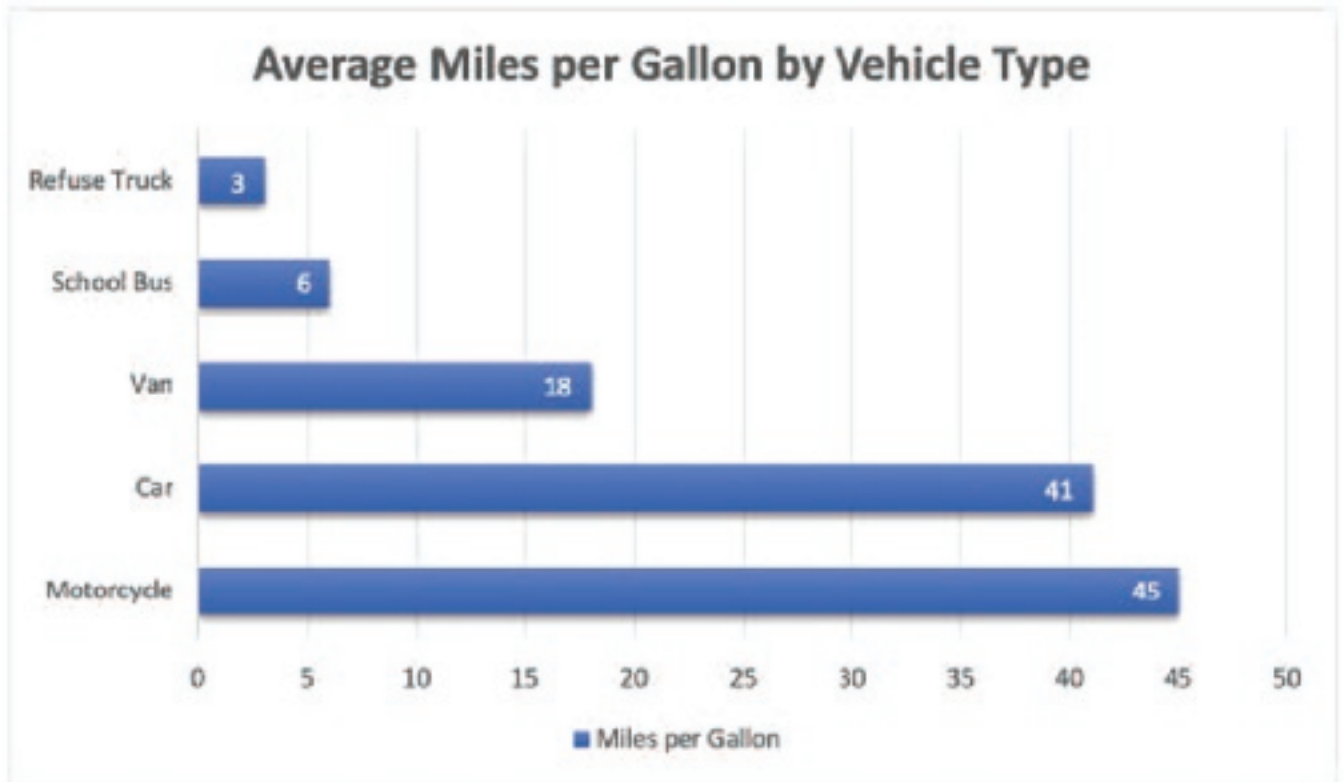
Station 2 Data Cards



Data Source: Reeve, B. (2020). How much difference does a headwind make when cycling. Retrieved from: <https://www.yellowjersey.co.uk/thedraft/how-much-difference-does-a-headwind-make-when-cycling/>



Data adapted from: Bialystocki, N., & Konolessis, D. (2016). On the estimation of ship's fuel consumption and speed curve: A statistical approach. Journal of Ocean Engineering and Science, 1(2), pp 157-166.



Data adapted from: Source: Federal Highway Administration. Highway Statistics 2016, Table VM-1; Calculated from statistics found in American Public Transit Association's Public Transportation Fact Book 2017; Gordon, D., Burdelski, J., and Cannon, J. S. Greening Garbage Trucks: New Technologies for Cleaner Air. Inform, Inc. 2003; American School Bus Council. National School Bus Fuel Data.

Microscopic Image Cards

Carpet



Floor tile



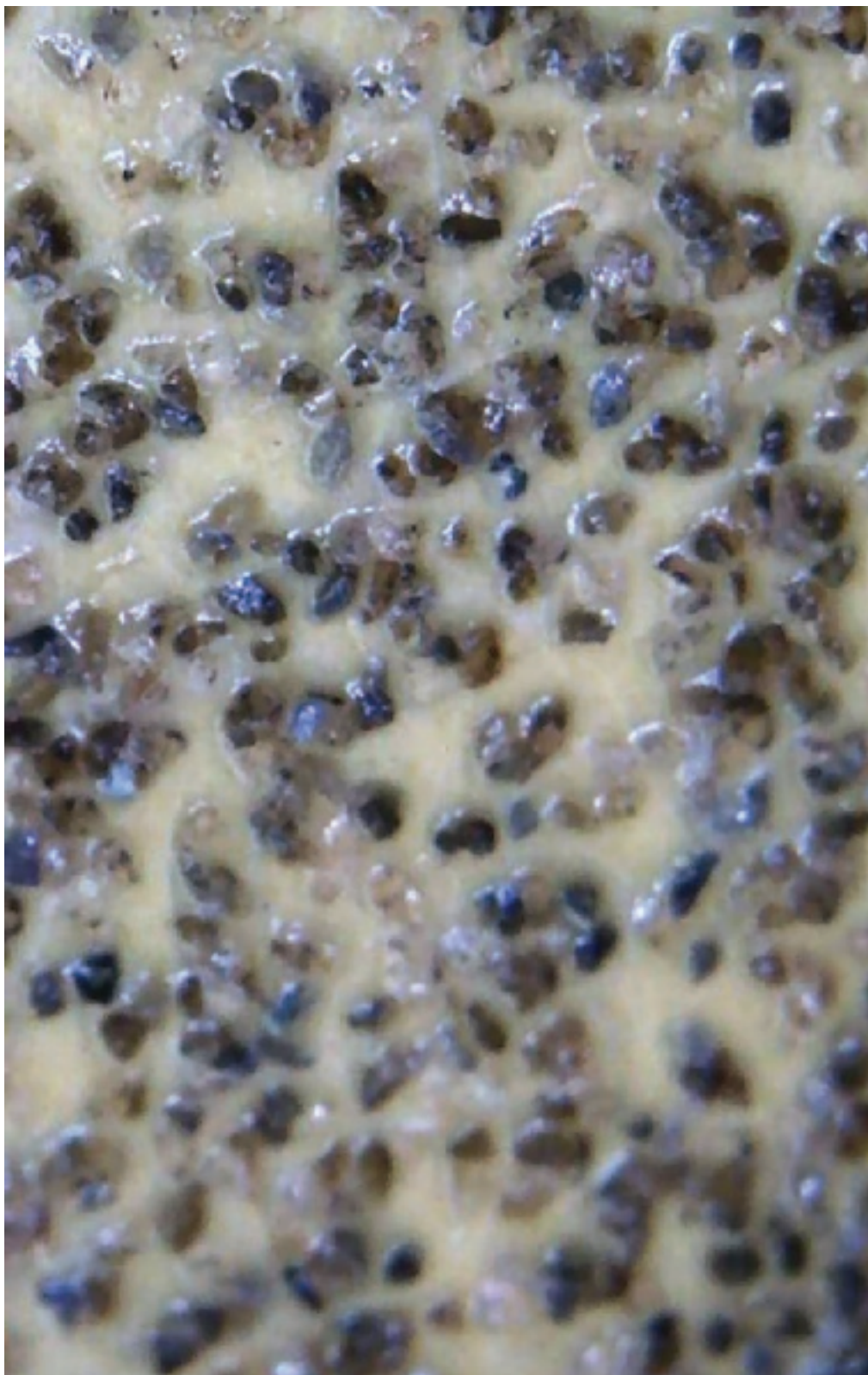
Fine sandpaper



Medium sandpaper



Coarse sandpaper



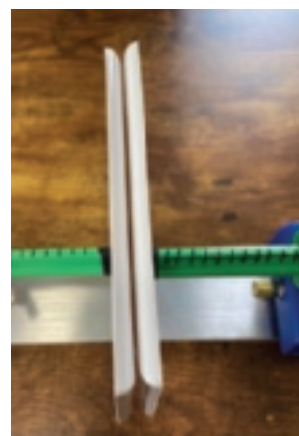
Cushioning Materials Testing Procedures

Establishing a Baseline Reading (Control)

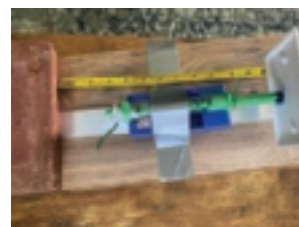
1. Set up your ramp so that it matches your teacher's setup using the flooring, track, brick, and binders or books. Make sure that your ramp is at the same angle and height as your teacher's ramp.
2. Get the electrical plates and sticky tack. Place the sticky tack slightly below the middle of the electrical plates. Use sticky tack to put the electrical plates on the ends of the spring scale rods. Make sure the curved edges of the electrical plates (the backs) are facing towards the carts.



3. Using a scale, add clay to your carts until both carts weigh exactly 200 grams each.
4. Place your carts on the track. Bring the two carts together and make sure that the electrical plates are not touching the track as they move.
5. With the two carts together, adjust the electrical plates so that they are flat against each other with no big, visible gaps between them. Try to line up the edges and corners the best you can.



6. Place the cart with the twist tie collar near the bottom of the ramp with the electrical plate facing up the ramp. Tape the cart down about 4 inches from the bottom of the ramp.



7. Confirm that the force collar is on the spring scale on the cart at the bottom of the ramp. Make sure that it is secure but can still easily move when the plunger is pushed in. Adjust the force collar on the scale so that it is at the base of the rod.



8. We need to establish a baseline reading so we can compare the peak force of the control collision with the peak force of the collision using a potential protective material. To do this, place the second cart at the top of the ramp with the electrical plate facing down the ramp. Release this cart towards the nonmoving cart at the bottom of the ramp.
9. Observe where the twist tie collar comes to rest on the rod on the spring scale. Record the data in the chart found at the end of this instruction set. Remember, each little line represents 1/10 of a newton. Each larger line represents 0.5 newtons.



10. Run this test 5 more times using steps 7–9 to check the accuracy of the readings.
11. Find the average of the force collar readings at the bottom of the table.

Force Collar Readings <i>without</i> Potential Protective Material	
Trial	Force collar reading (N)
1	
2	
3	
4	
5	
6	
Average reading	

Testing a Protective Material (Experimental)

1. Place transparent tape circles on the back of the potential protective material you are testing.



2. Tape the material to the front of the electrical plates on each cart.



3. Using a scale and the clay, adjust the weight of the carts to 200 grams.
4. Make sure that the pieces of your material on the electrical plates on the two carts touch the best they can without any gaps when they are brought together.



5. Adjust the force collar on the spring scale of the nonmoving cart so that it is at the base of the rod.
6. Place the colliding cart at the top of the ramp with the material facing down the ramp. Release the cart towards the nonmoving cart at the bottom of the ramp.
7. Record where the twist tie collar comes to rest on the chart found at the end of this instruction set. Each little line represents 1/10 of a newton. Each larger line represents 0.5 newtons.
8. Run this test 5 more times using steps 5–7 to check the accuracy of the readings.
9. Find the average of the force collar readings at the bottom of the table.

Force Collar Readings <i>with</i> Potential Protective Material	
Trial	Force collar reading (N)
1	
2	
3	
4	
5	
6	
Average reading	

Finding the Average Reduction in Peak Force

To figure out how well the material worked to reduce peak forces, we have to subtract the average force reading of the materials test from the average force of the control test without the materials.

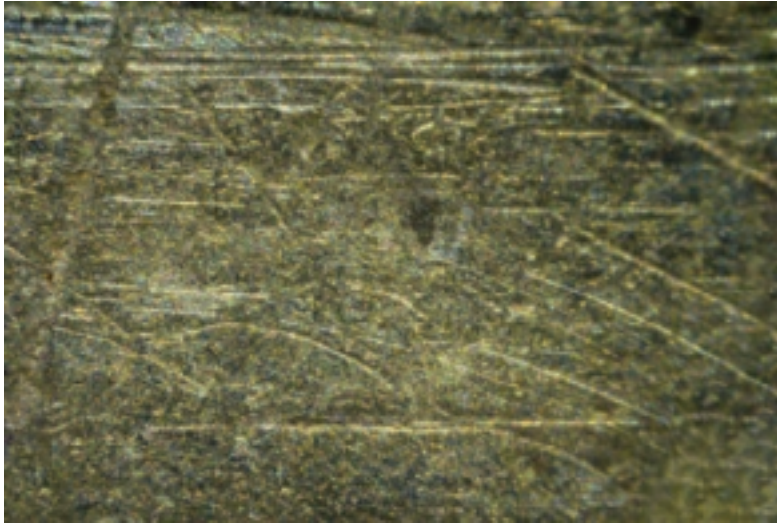
average of test <i>without</i> materials	_____N
(subtract)	—
average of test <i>with</i> materials	_____N

average amount of peak force reduction	_____N

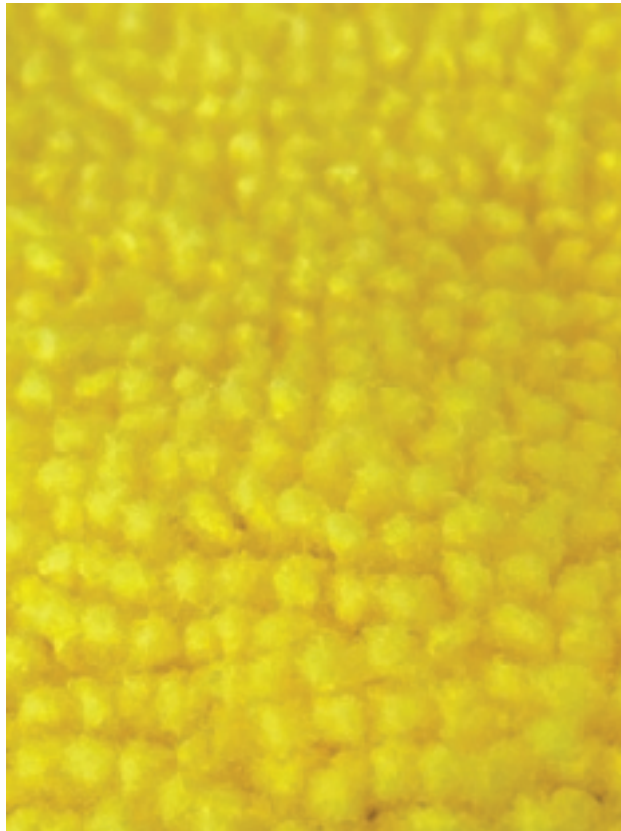
The average peak force reduction of our material _____ is _____ newtons.

Up Close Images

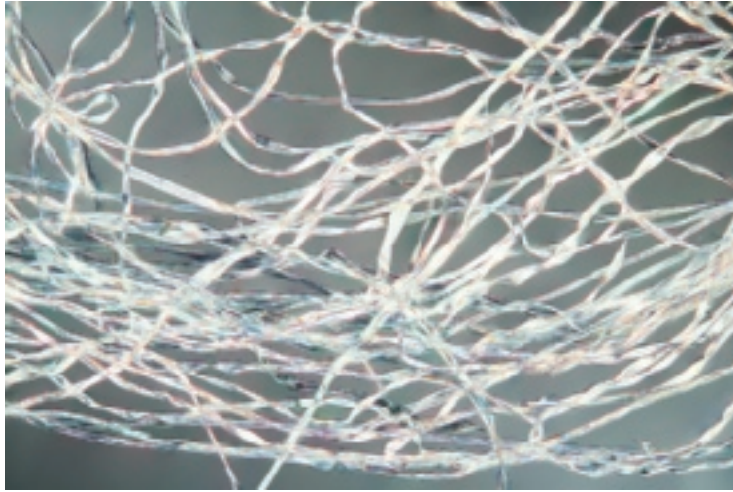
Metal under a microscope



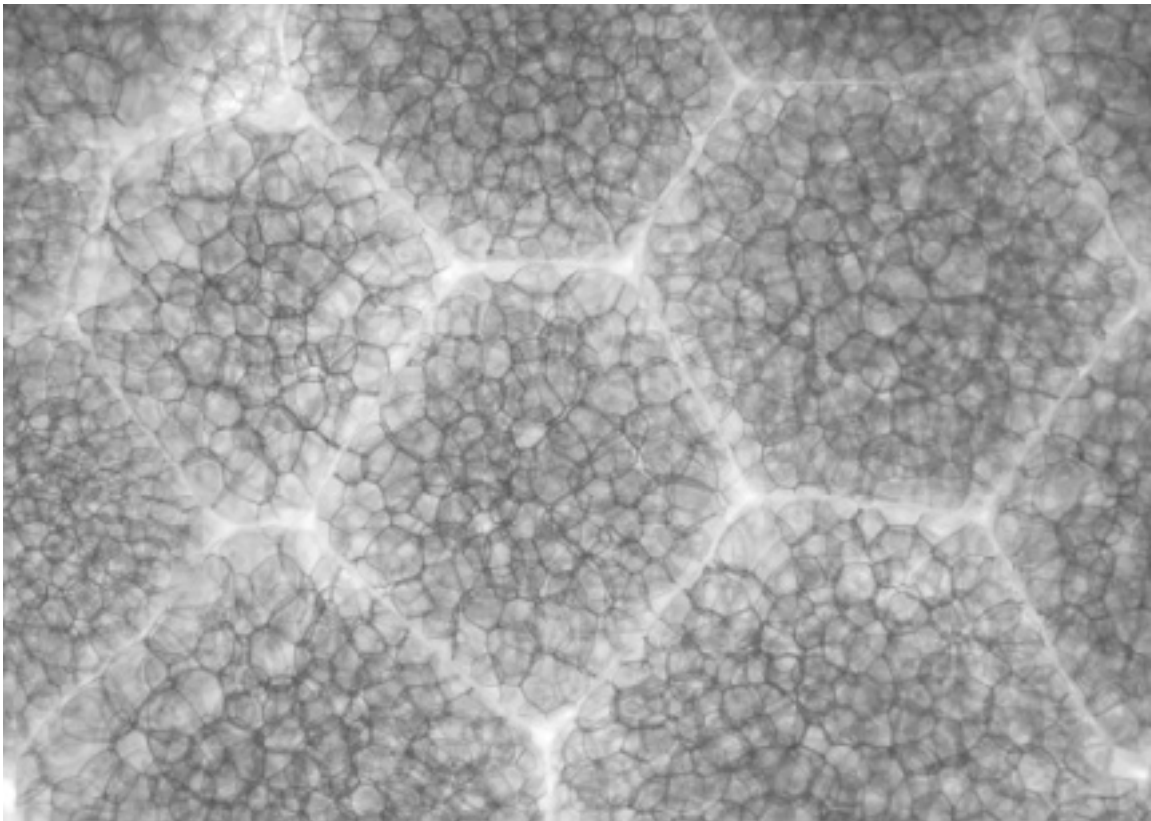
Cotton fabric up close



Cotton fibers under a microscope



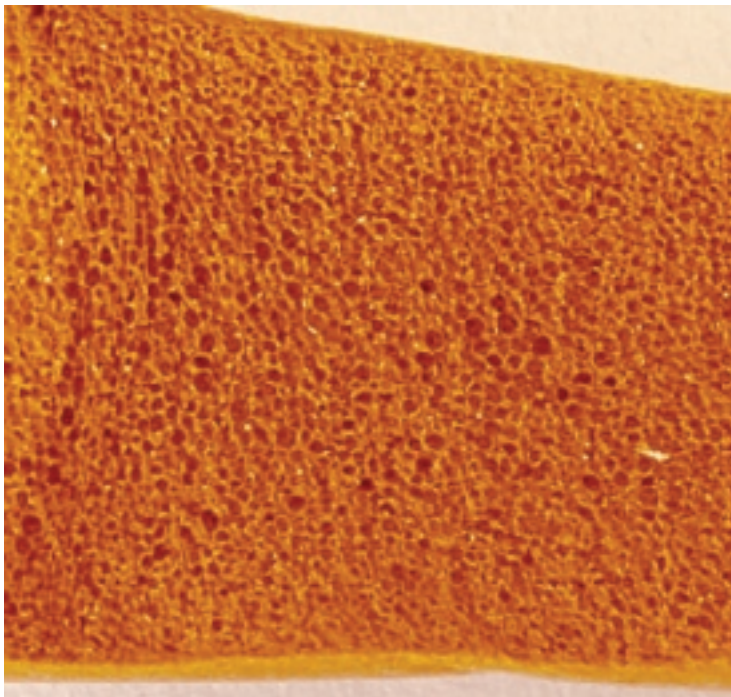
Styrofoam under a scanning electron microscope



Bubble wrap up close



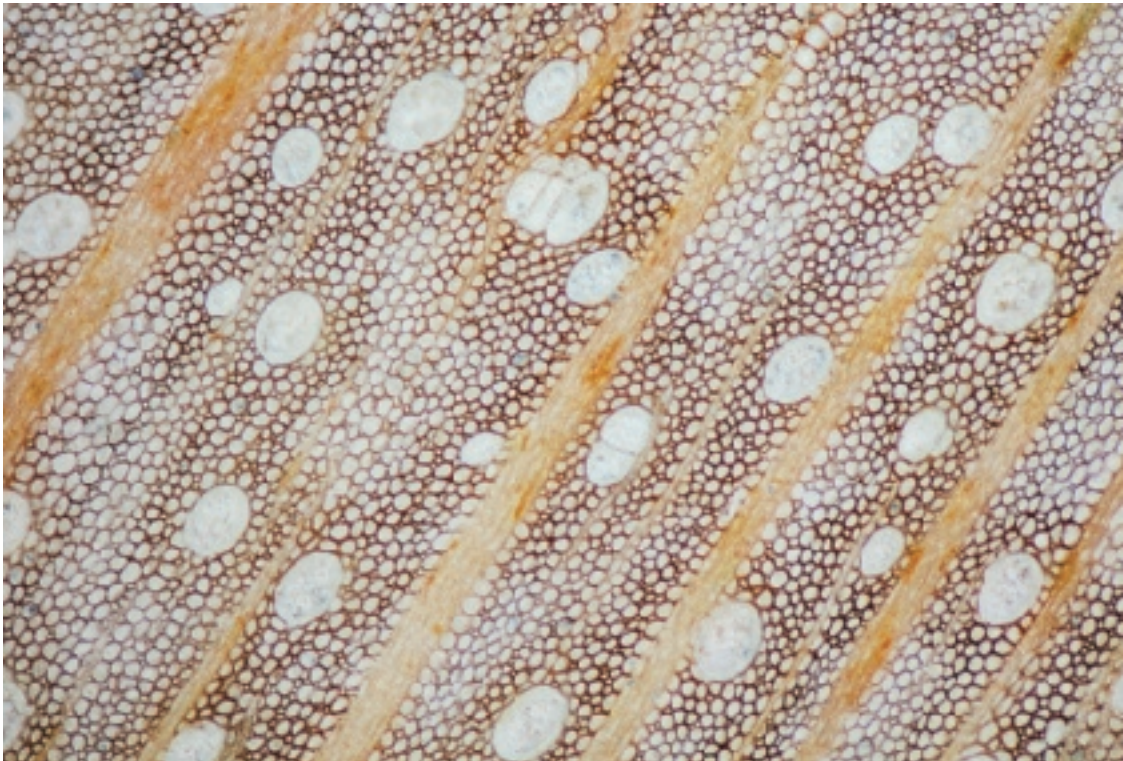
Foam earplugs up close



Corrugated cardboard up close



Lightweight wood under a microscope



Additional Material Considerations Matrix

Material	Force reduction	Reusable (can withstand multiple impacts)	Robust (good for heavy items)	Recyclable (accepted in curbside recycling)	Biodegradable (backyard compostable)	Low material cost	Low cost to work with the material in a design	Water used for production	Does not contribute to climate change
Cotton balls	●●●●●	●●●●●	●	●	●●●●●	●●●	●●●	●	●●●
Wood	●	●●●●	●●●●●	●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Urethane (earplugs)	●●●●●	●●●●●	●●●●●	●●●	●	●	●	●●	●
Styrofoam	●●	●	●●	●	●	●●●	●●●	●●●●	●●
Corrugated cardboard	●	●	●●●	●●●●●	●●●●●	●●	●●●	●●●	●●●●
Paper	●●	●	●	●●●●●	●●●●●	●●	●●	●●	●●●
Air pillows	●●●	●●●	●●	●●●●●	●	●●●	●●●	●●●●	●●●
Large bubble wrap	●●	●●●	●●	●●●●●	●	●●●	●●	●●●●	●●●
Small bubble wrap	●●	●●●	●●●	●●●●●	●	●●●	●●	●●●●	●●●

Data Source: Michigan State University, School of Packaging

Reading: How does touch work?

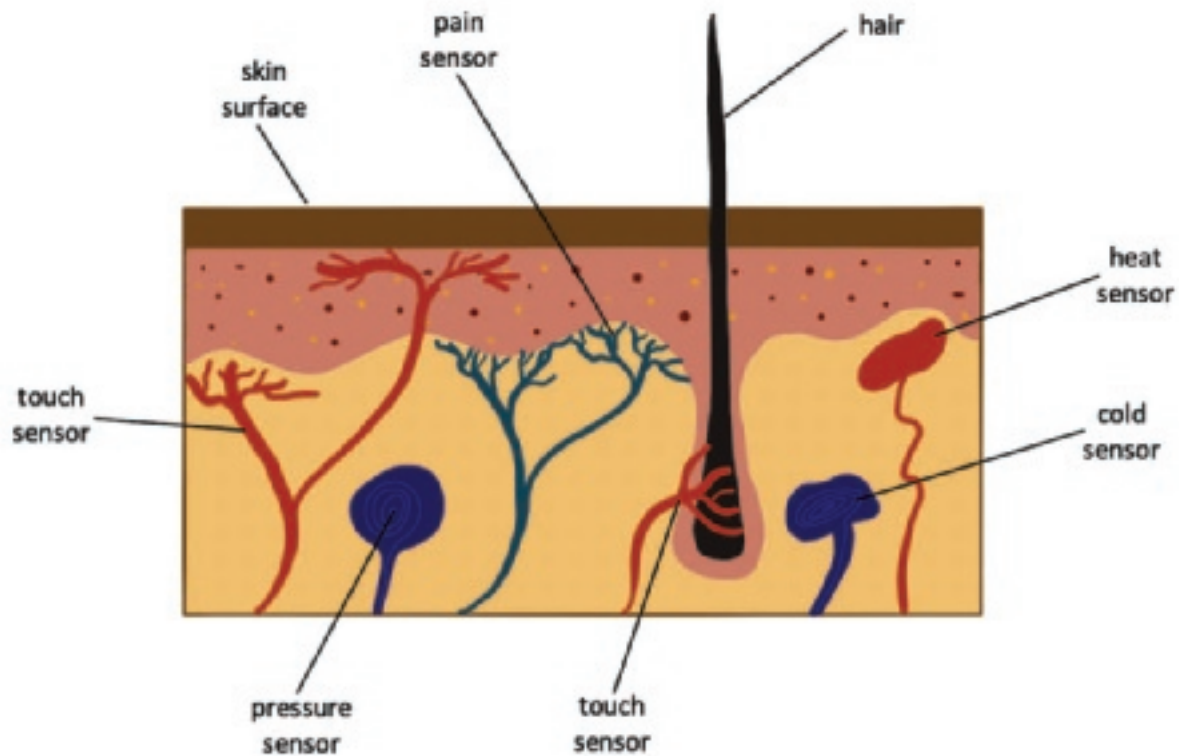
How does our sense of touch work?

Do you know anyone who is blind? How do they navigate the world? You may be thinking that they use other senses like hearing and touch. People without sight can still do many of the things people with sight can do. For example, blind people often use their fingers to read by feeling patterns of raised dots in books, on restaurant menus, or on signs. Braille is a coding system that allows people who are visually impaired to read by pressing their fingers onto raised dots that represent sequences of letters forming words and sentences. The Braille alphabet is shown in the figure below. Do you think you could feel your name in raised dots using this system?

A	B	C	D	E	F	G	H	I	J
⠁	⠃	⠉	⠙	⠑	⠋	⠗	⠓	⠊	⠞
K	L	M	N	O	P	Q	R	S	T
⠅	⠌	⠍	⠝	⠕	⠏	⠒	⠚	⠎	⠟
U	V	W	X	Y	Z				
⠥	⠦	⠡	⠭	⠣	⠵				

If you are a sighted person, you also have the ability to recognize objects using only your sense of touch. If you close your eyes, you could probably identify a cell phone, a pencil, or a feather using only your fingers. You could press on the smooth glass surface of the cell phone and feel the pointed end of the pencil and the lightness of the feather. How are you able to do this?

Your skin is an amazing organ covering the surface of your body. It has millions of sensors that sense feelings in many different forms like, pain, temperature, and pressure. Different kinds of sensors respond to different sensations. One square inch of your skin contains about 200 sensors for pain, fewer than 10 for temperature, and about 15 for light touch and pressure from forces applied to your skin.

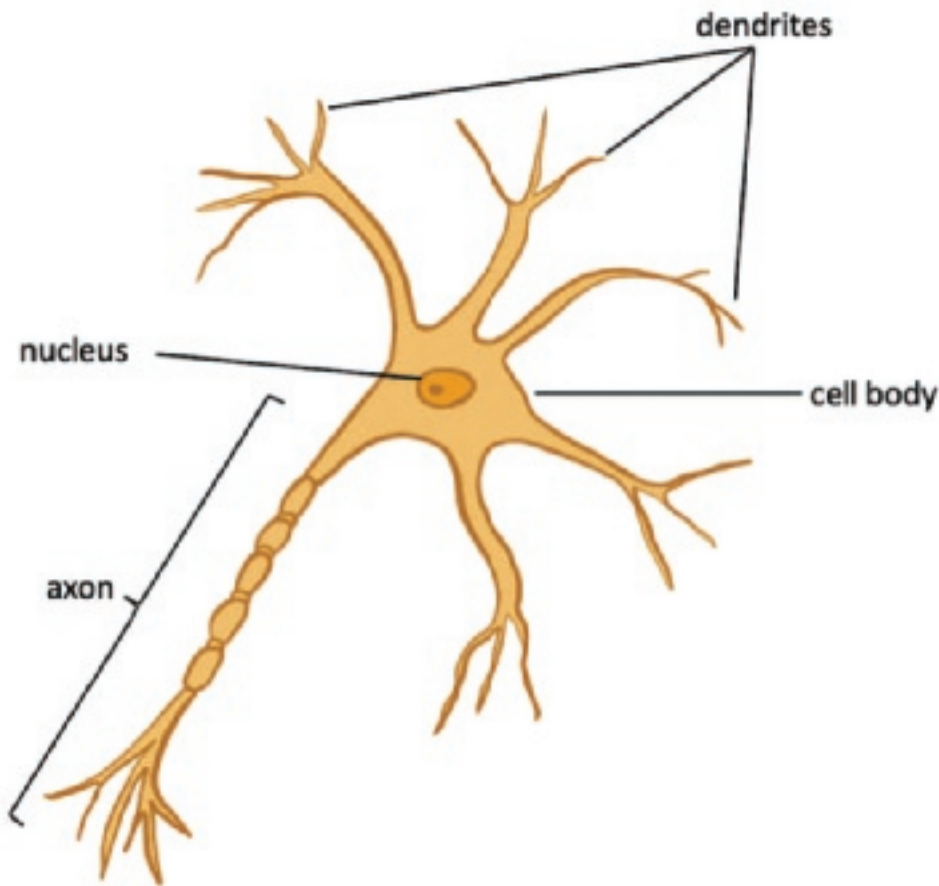


Why do you think there are so many pain receptors? You may be thinking that it would be a good thing to be unable to feel pain. But this would actually be very dangerous. Imagine tripping, falling down, and breaking your arm due to the forces between your arm and the ground. If you can't feel pain, you might not know you were seriously hurt. You might go about your day causing even more damage to your arm. People who can't feel pain have a very rare condition called *congenital analgesia*. These people must be very careful not to hurt themselves.

The heat and cold sensors in your skin help you regulate your body temperature. They signal when to put on a warm coat or seek out shade on a hot, sunny day.

Pressure and touch sensors detect and respond to contact forces between your skin and other things. These sensors are very sensitive to any deformation they experience in their structure. Touch sensors that are attached to hairs deform as the hair comes in contact with something else and moves. This can be something as gentle as the push from moving air in a light breeze. Other sensors, like pressure sensors, can help you detect when something presses firmly down on your skin.

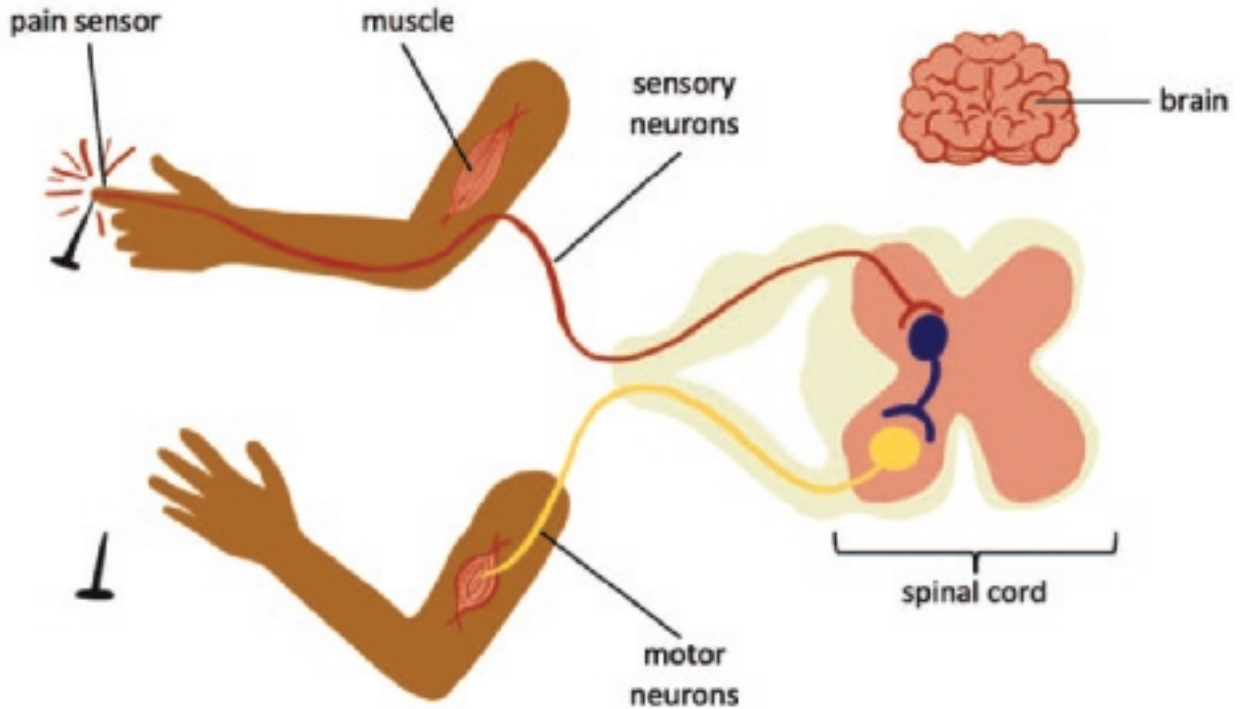
When these sensors are deformed they send a chemical signal to nerve cells that they are connected under your skin. These nerve cells are called *neurons*. An image of the structures that make up a neuron is shown below.



Neurons are very long cells with specialized ends that can send or receive chemical signals throughout your body to relay information. Sensory neurons in your skin send information to neighboring neurons which, in turn, send signals to your brain and spinal cord.

Your brain and spinal cord process these signals and send response signals to different parts of your body through a different type of neuron called a *motor neuron*. The motor neurons send signals that can trigger a response in the cells in that part of the body.

Signals that protect us from hurting ourselves usually move from sensory receptors in our skin to our spinal cord. Our spinal cord then sends a signal through motor neurons that results in some kind of fast action. For example, if your hand touches something sharp with too much force, a signal goes to your spinal cord and causes the cells in your arm muscles to contract quickly, resulting in you pulling your hand away before you even realize what happened.



When an immediate response isn't needed, a signal travels from sensory receptors in your skin to your brain. Then your brain interprets the signal, and you decide how you want your body to respond. Imagine you wake from sleep feeling uncomfortable pressure on your shoulder from being in the same position for too long. You decide to roll over to get more comfortable. To do this you will need to send a signal to those muscles in your body to move yourself around.

So remember, when you feel forces on your skin they are really deforming specialized structures (pressures sensors) under the skin, and these structures in turn relay signals through a connected series of nerve cells to your brain.

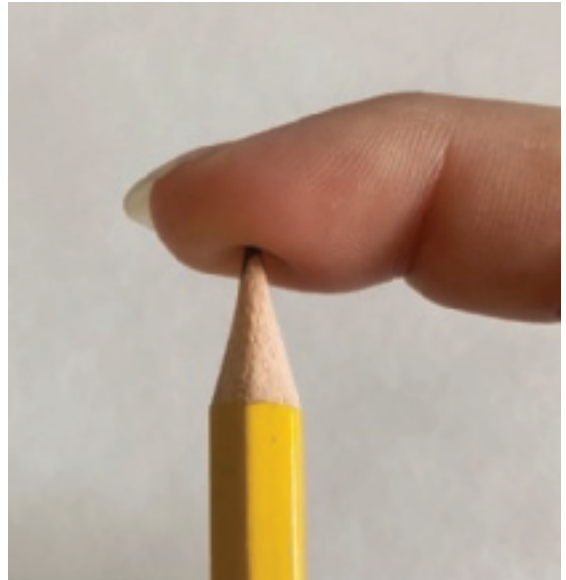
Reading: How do we sense different textures?

When we touch a material, we feel the texture of that material. We can tell if something is hard or soft just by placing our skin on the object. Have you ever considered how we can tell if something is hard or soft? It turns out the answer is deformation due to a contact force!

We learned in Lesson 5 that we can feel objects when the pressure sensors in our skin deform. We also learned these pressure sensors, or force detectors, are all over our body. It is estimated that you have roughly 150,000 of these in each hand! The special sensors for detecting force are called *mechanoreceptors*. Let's learn more about how the skin senses different textures and softnesses.

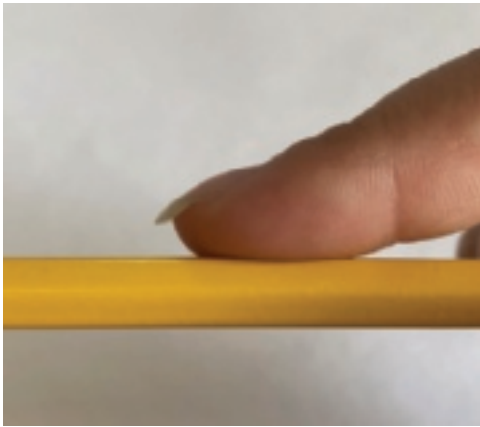
The feeling of sharp vs. dull

When your finger touches a surface, part of your finger deforms. Things that feel sharper deform more of your finger and touch less surface area. Take a finger and touch your desk. Your finger touches the surface and then it starts to deform so that the entire pad of your finger is touching the surface of the desk. Now, take your pencil and use the point of your pencil to touch the pad of your finger. Does it feel different? The reason that the pencil feels sharper is because it makes your finger deform more and less surface area is in contact with the object. The table felt smooth or dull because it did not indent, or deform, your finger as much as the pencil point. The table also pressed on the whole pad of the finger, not just a small area.



This pencil causes a lot of deformation to the pad of the finger, but it touches a very small surface area at the lead point. Because it touches such a small area and there is a large deformation, the brain senses this pencil as sharp.

The feeling of smooth vs. rough



As the finger runs across this pencil, it does not encounter multiple areas of deformation and the pressure is consistent on the pad of the finger. This causes the brain to sense the pencil side as smooth.

When you run your hand across different surfaces, some feel smooth and others feel rough. Run your hand across a surface that is rougher, like the stitching on your backpack, a zipper, or the metal part of your pencil. Now run your hand across a surface that is smoother, like the top of your desk or the side of your pencil. Which one had more areas of deformation as you moved your finger across the surface? The rough surface makes many different spots on your finger deform as your finger moves across the surface, and the smooth surface does not have as many spots that cause deformation to the finger on multiple locations. The smooth surface does not deform your finger as much when your finger runs across the surface.

The feeling of soft vs. hard

When your hand touches something soft, the soft item deforms around your finger. The soft surface is deformed due to the pressure of your finger pushing on it. If your finger deforms the surface instead of the surface deforming your finger, it feels softer. Cotton balls feel soft because of how much they deform when we apply pressure. The surface touches a very large part of our fingertips with very little force being applied. Our bodies know when we are applying pressure, and the more we apply pressure without the resistance, the softer an object feels.



This cotton ball deforms when a contact force from the finger is applied. The finger senses that it is in contact with the cotton ball, and the cotton ball deforms more than the pad of the finger. This causes the brain to sense the cotton ball as soft.

How our brains receive the signal

Our sense of soft vs. hard depends on the amount of pressure and deformation on our skin. When the finger is deformed, it sends signals through our nerves to the brain that then interprets the texture of the objects. Our brain turns this signal into information that we can use.

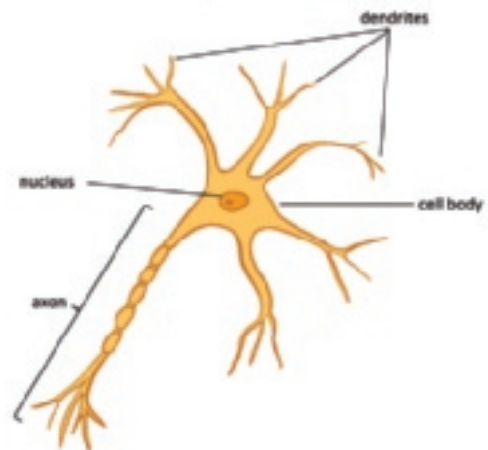
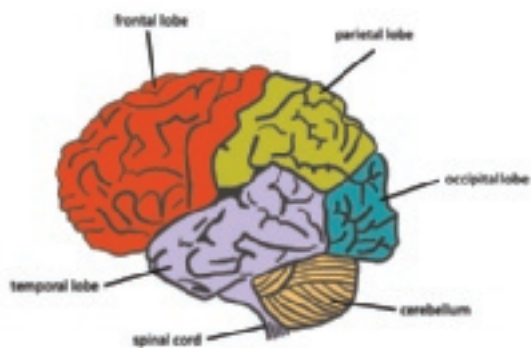
Reading: Anatomy of a Bike Helmet

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, located in the back of your head, 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.



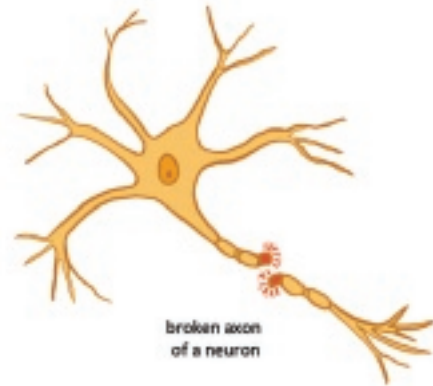
When the head collides with the ground, the brain can collide with inside of the skull.

You may remember that long nerve cells called neurons are responsible for your sense of touch and for sending messages to and from your brain and spinal cord. Your brain contains neurons too. You may also remember that neurons send chemical signals from one axon of a cell to another cell to communicate with each other. Neuron activity and connections between neurons in your brain are very important to memory formation.



Contact forces to your head can transfer energy to your brain, causing it to twist and collide with the inside of your skull. This can result in a concussion. Contact forces to the brain can cause cell damage. Some effects of cell damage include headaches, trouble concentrating, and memory loss. An impact to the head that causes a concussion can cause the long, connecting nerve cells in the brain to stretch and break. Some nerve cells can recover from injury, but more severely injured cells lose their ability to send signals.

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Consider:

- 1) How do you think concussions and nerve cell damage can lead to memory loss?
- 2) What might happen if a person gets multiple concussions?

Wearing a helmet during certain activities, like cycling, can protect your brain from injury and reduce the chance of getting a concussion. You may be wondering why helmets look the way they do. The thickness and shape of all helmets are purposely designed to protect your brain from impact forces caused by collisions. Helmets designed specifically for bicycle riders are important safety gear that can protect your brain. In fact, wearing a helmet can reduce the amount of peak forces on the skull and can lead to 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 Product 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 is approved by the Consumer Product Safety Commission. 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.

Companies want helmets to stabilize your head and your brain during a fall. But they also want them to meet the criteria of looking 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!

Stop and think:

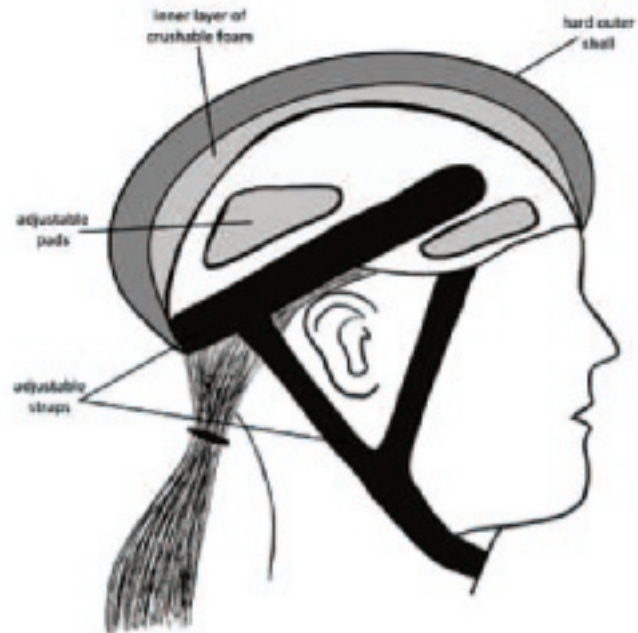
3) Helmets have other design features like adjustable straps and pads to ensure a snug and stable fit for many different head sizes. Why is a snug and stable fit important?

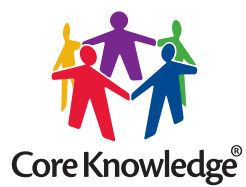
If you have a bicycle helmet that doesn't meet current safety standards or that doesn't fit well, you should replace it. You should also replace your helmet if it's been in a collision because it might not effectively protect you in another collision.

Consider:

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

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





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