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

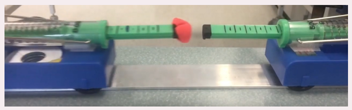
PREVIOUS LESSON

We carried out investigations to explore what happens when two objects of different speeds and different masses come in contact with each other and learned that each object applies a force on the other object. We argued from evidence that the amount of force is the same on each object, regardless of the speed or mass of each object.

THIS LESSON

INVESTIGATION

1 day



We carry out an investigation to determine how different materials impact the amount of force on each object. We argue from evidence that the amount of force is the same on each object, regardless of what each object is made of.

NEXT LESSON

We will consider what it means for solid matter to "push back." This will lead us to think about springs, which we all agree push back when you push on them. We will use springs and clay as a physical model for how solid matter can push back.

BUILDING TOWARD NGSS

MS-PS2-1, MS-PS2-2

WHAT STUDENTS WILL DO

Plan and carry out an investigation *to provide evidence that for any pair of interacting objects in a system, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first.*

Develop and use models to describe *the magnitude and direction of the forces that result when the two objects in the system defined by boundaries interact in a collision.*

WHAT STUDENTS WILL FIGURE OUT

Regardless of the composition of the two objects in the collision, the forces are equal and in opposite directions.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION** Ask students to recall what was learned in the prior lesson.	A-C	class word wall, chart paper, markers,
2	31 min	**COMPARING FORCES: DIFFERENT MATERIALS** Students design an investigation to see how the forces compare during a collision between objects made of two different materials. As in previous investigations, they discover that the forces between the two objects is the same.	D-H	carts, two 5 N push-pull spring scales, two2 cm pieces of fun-tack, a variety of materials to put on the end of the push-pull spring scales,
3	3 min	**NAVIGATION** Help students think through next steps.		
4	3 min	**HOME LEARNING** Students complete an home learning activity that can be used to assess understanding that the forces are always the same regardless of material and to demonstrate that they can draw a force diagram.	I	loose leaf paper,

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • loose leaf paper	• carts • two 5 N push-pull spring scales • two2 cm pieces of fun-tack	• class word wall • chart paper • markers • a variety of materials to put on the end of the push-pull spring scales

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

This lesson will use the same setup as Lesson 5. It will use the carts with attached hook and loop fasteners on push-pull spring scales and washers. You will need to get out the mounting putty and a variety of objects that students can stick on the end of the plungers such as clay, golf balls, marshmallows, pieces of wood, etc.

You will want to prepare the class data table chart as you did in Lesson 5 *Unknown material with identifier: cf.l6.01* again, removing the columns for predictions.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

Students may think that when they see more damage on one object versus another during a collision that the force might be greater on the material that deforms with less force. Students will learn that during a collision, the forces on each object are the same in amount but opposite in direction, regardless of what the materials are in the collision.

Where We Are NOT Going

We will not explore why the forces are the same. This will be explored in the next lesson. We will also not explore why the effect of the collisions are the same (e.g., the mass is different so the changes in motion are different). This will be taken up in a later lesson.

LEARNING PLAN for LESSON 6

1 · NAVIGATION

6 min

MATERIALS: science notebook, class word wall, chart paper, markers

Take stock of what the students figured out last class. Say, *Let's remind ourselves of a couple of new ideas we learned last time.* Show **slide A**.

Suggested prompt	Sample student response
What did we learn about how the forces compared between two objects that collided with different speeds?	*That the forces are the same on each object but opposite in direction.*
What did we learn about how the forces compared between two objects with different masses?	*That the forces are the same on each object but opposite in direction.*

Say, *Let's recall how we used force diagrams for each of these situations.* You may want to use student work from the previous lesson here or show a diagram that you have done. Show **slide B**.

Remind students of the force diagram conventions. Say, *Remember that we have to define the objects in our system. We can call this "setting the boundary of the system." We don't want to include everything. Then we color-code the object (Left = Blue and Right = Red), include color-coded arrows, and include labels (Force ON ______ FROM ______). The length of the arrow tells us how much force is on each object.*

Say, *Let's remind ourselves of a few things we learned from a previous lesson. Do you remember how we used the laser pointers?* Show **slide C**.

Suggested prompt	Sample student response
What happens to all objects, even really strong ones, when forces are applied? What was our evidence?	*They either bend or break. We saw this in previous lessons where some things bent and some things broke depending on the material, thickness of the material, and how much force was applied. Even really hard things bent like we saw with the laser pointer.*
What happens when more force is applied to an object?	*When more force was applied, the object bent even more until it either broke or bent out of shape.*
So we've investigated two carts colliding with different speeds and then with different masses. Can you turn to an elbow partner and talk about what was kept the same, or controlled, in each of these cases?	*The first time, we changed the speed of the carts and kept the carts the same--the same mass and the same objects that were colliding (the plungers). The second time, we changed the amount of mass and kept the speed and the objects that were colliding the same.*
So we've investigated different masses and different speeds. What's left for us to test?	*How the forces compare when we have two different materials that are colliding.*

2 · COMPARING FORCES: DIFFERENT MATERIALS

31 min

MATERIALS: science notebook, carts, two 5 N push-pull spring scales, two2 cm pieces of fun-tack, a variety of materials to put on the end of the push-pull spring scales

Guide students in setting up the investigation.

Show **slide D**. Say, *So today, let's investigate how the forces compare when we have objects made of two different materials collide. Before we start, let's think about how we might answer this investigation question.* ✱

Suggested prompt	Sample student response
What is the independent variable in this investigation question?	*We will have to change the materials.*
What is the dependent variable in this investigation?	*We will have to measure the force.*
What tools should we use to measure the dependent variable?	*Maybe we can use the push-pull spring scales and the slow-motion video from the prior lesson to test the amount of force.*
What measurements will we look for on these tools to help us answer our question?	*We will look to see how the amount of force compares by looking at how far the plunger pushes in. If it is the same amount of push in, then we know it's the same amount of force. If it's a different amount, then we know that the forces are different.*
How can we change the independent variable?	*We can attach different materials to the push-pull spring scales. We will have to figure out a way to attach the different materials to the spring scales.*
How might we collect enough data to answer the question?	*Maybe each group could try out different materials and then report back what we find out. Maybe like last time, we will have to try each collision a number of times.*
How could we design an investigation to test this question?	*Accept all responses.*
If we use the push-pull spring scales, what will we see if the forces are different? The same?	*If the forces are the same, we'd see the two plungers going in the same distance on the slow-motion video, and if the forces were different, we'd see one plunger going in further than the other plunger.*

Share a potential procedure to guide the investigation. Show **slide E**.

ADDITIONAL GUIDANCE

You may want to skip **slide E** if you are able to solicit and guide student thinking about how they might set up an investigation in ways that meet all the steps presented in **slide E**.

If you show them **slide E**, you can ask them to evaluate this procedure.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

In this investigation, we help students think about elements of investigation design. They help guide what the variables are and how they might be measured and changed. Students also think about how much data will be needed to answer the question.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

This last question asks students to determine if there is sufficient data to support any patterns they are noticing in the data.

ALTERNATE ACTIVITY	Some students may have a strong background in the practices within *SEP: Planning and Carrying out an Investigation*. Other students may require more practice. Use this slide here if need be and/or come back to it if (once you begin) students seem to be struggling with their designs.

Say, *Thanks for sharing your ideas.*

Suggested prompt	Sample student response
What do you think are the benefits of this procedure?	*Accept all responses.*
What do you think are the limitations of this procedure?	*Maybe it will be hard to see the amount of force in the collisions as they happen quickly and the push-pull spring scales are not very precise.*

Say, *We have putty that will help mount different materials to the push-pull spring scales.*

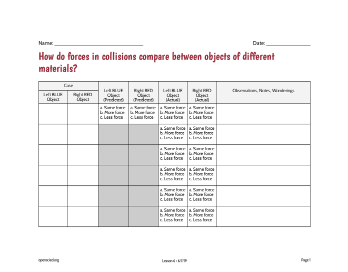
Here are sample materials that you might use:

- play dough
- modeling clay
- golf balls
- pieces of wood
- marshmallows

ALTERNATE ACTIVITY	You can provide other materials or have students bring in materials that they are interested in testing.

Pass out *How do forces in collisions compare between objects of different materials?* for students to record their results and their peers' results. On chart paper or on a chalk/whiteboard, duplicate the table. You do not need to have the prediction columns.

As students are starting these investigations, walk around and ask them what their predictions are and why they think they might be correct. As they start to collect data, ask them what they are thinking now about how forces are comparing. They should be noticing that the forces between the two different objects are the same as they notice that the push-pull spring scales are being pushed in the same amount.


Name: ______________ Date: ________

How do forces in collisions compare between objects of different materials?

Case: Left BLUE Object	Case: Right RED Object	Left BLUE Object (Predicted)	Right RED Object (Predicted)	Left BLUE Object (Actual)	Right RED Object (Actual)	Observations, Notes, Wonderings
		a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	
				a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	
				a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	
				a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	
				a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	
				a. Same force b. More force c. Less force	a. Same force b. More force c. Less force	

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ADDITIONAL GUIDANCE	If students need additional challenge or are done early, have them draw a force diagram of their objects in the collision. Ask them to look at the class data and notice if there are any patterns emerging.

Motivate a Building Understandings Discussion.
As student results start to come in, show **slide F** and have students begin to discuss the questions on the slide.✱

KEY IDEAS	**Purpose of this discussion:** Help students come up with another generalization that adds to the rule that the force of impact will be the same on each object regardless of mass, speed, or material. **Look for:** • The force on each object is the same, regardless of the material.

If the data seems to be inconclusive, meaning that some students are seeing that the forces are different or that they cannot tell using their videos, show **slide G**.

Say, *Let us look at some slow-motion videos. This repeats one of the trials we did.*

To pause the video, push (K) or Space on your keyboard. Pressing the period (.) will nudge the video one frame forward. Pressing the comma (,) will nudge the video one frame backward.

Watch the videos. Return to **slide F**.

Say, *Now let's analyze this data. Let's take a look at the class chart. Give me a silent thumbs-up when you see a pattern.*

Suggested prompts	Sample student responses	Follow-up questions
How do the forces compare on each object in a collision when the objects are made of different materials? What evidence supports your claim?	*The forces are the same. We saw that almost every time with our tests and with the videos. It didn't matter what the two objects were, the forces were the same as the plungers pushed in the same amount.*	*That's right--we learned that even during the collisions, the amount of force is the same on each object, regardless of the materials. The speed and mass of the objects don't matter.* *So we can say that anytime two objects collide, the forces on the two objects will be the same!*
Did we gather enough data to answer our guiding question?	*It seems like across the six groups that the data is telling us we have a pattern.*	*That's right--also, we watched the videos and saw that with more precise tools that the amount of force was the same.*

Have students use this new idea with different phenomena. Show **slide H**. Say, *So we can now use this idea for some more complicated collisions.* Do a call-and-response for each of the questions.

Suggested prompt	Sample student response
What does it mean that the forces are the same on the golf ball and the golf club?	*The push on the golf ball is the same as the push on the golf club.*
What does it mean that the forces are the same on the bug and the car windshield?	*The push on the bug and the car windshield is the same.*

ADDITIONAL GUIDANCE	Note that this will be somewhat troubling for some students. How can the forces be the same when the results of the collisions are so very different? Because of Newton's second law, we know that less massive objects have greater changes in motion. This idea will be developed later on. If these questions come up, great! Include them in the navigation and have students write their questions down on notecards and add them to the Driving Question Board. They will also learn that because of the material, some materials deform and sometimes break. However, the forces on each object are still the same.

3 · NAVIGATION

3 min

MATERIALS: None

Say, he idea that the forces on objects in collisions are always the same regardless of mass, speed, or material seems kinda strange, right? How is it possible that a bug and a windshield have the same amount of force? What is causing that pushback? Let's investigate that in our next lesson.

Suggested prompt	Sample student response
*We have seen evidence that two things in a collision **push on each other**. And we have seen evidence that the size of the push during that collision is always the same. What do you think about that?*	*It's kind of weird! How can a tiny bug really be pushing as much as the windshield pushes back on it?*
If that's really true, where do you think the push of the bug or any of the example collisions we've been thinking about (ball on bat etc.) might be coming from?	*I don't know! We saw that there is the same push between the different objects, but it's hard to see where that could be coming from.*

4 · HOME LEARNING

3 min

MATERIALS: loose leaf paper

Prepare students for the home learning activity. Show **slide I**.