Forces
Lesson 2b: How Can We Represent More Than One Force?

Grade 3	**Length of lesson:** 40 minutes	**Placement of lesson in unit:** 2b of 6 two-part lessons on forces
Unit central questions: What makes something start to move? What makes something stop moving or change direction?		**Lesson focus question:** How can we draw the forces pushing or pulling an object when we can't see them?
Main learning goal: The forces acting on an object have a strength and direction that can be represented using arrows of various lengths and directions.		
Science content storyline: Arrows can be used to represent the strength and direction of the forces acting on an object. The direction of an arrow represents the direction of the force, and the length of an arrow represents the strength of the force.		
Ideal student response to the focus question: Arrows can represent the strength and direction of the force acting on an object. A longer arrow means a bigger, stronger force. A shorter arrow means a smaller, weaker force. The direction of an arrow shows the direction of the force. Arrows pointing in opposite directions represent forces pushing or pulling an object in opposite directions.		

Preparation

Materials Needed • Science notebooks • Chart paper and markers • Rolling cart (from lesson 1a) • 3 foam-board arrows of different lengths (from lesson 2a) • Toy car (Hot Wheels or similar type of miniature car) (1 per pair) • Arrows template • Envelope containing 6 paper arrows of varying lengths (2 short, 2 medium, and 2 long) (1 set per pair) **Student Handouts** • 2.1 What Are the Forces? (1 per student)	**Ahead of Time** • Review section 4 (Net Forces) in the content background document. • Use the arrows template to cut out the arrows and assemble the envelopes.

Lesson 2b General Outline

Time	Phase of Lesson	How the Science Content Storyline Develops
4 min	**Link to previous lesson:** To review science ideas from the previous lesson, the teacher engages students in analyzing a diagram using an arrow to represent a force acting on a cart.	• The forces acting on objects have a strength and direction that can be represented in a diagram using arrows of various lengths and directions.
2 min	**Lesson focus question:** The teacher reviews the focus question from the previous lesson: *How can we draw the forces pushing or pulling an object when we can't see them?*	
8 min	**Setup for activity:** Students consider what happens when more than one force acts on an object at the same time.	• The forces acting on an object have a strength and direction that can be represented in a diagram using arrows of various lengths and directions. • Arrows pointing in different directions show that forces are acting on an object in different directions.
15 min	**Activity:** Students use toy cars and paper arrows to represent multiple forces acting on an object. They use the arrows to show the direction and strength of the forces and the resulting movement of the cars.	• The forces acting on an object have a strength and direction that can be represented in a diagram using arrows of various lengths and directions. • The length of an arrow represents the relative strength of the force exerted on an object. • The direction of an arrow represents the direction of the force acting on an object. Arrows pointing in different directions show that forces are acting on an object in different directions. • If more than one force is acting on an object, we can predict the object's motion and the relative strength of the forces by comparing the lengths of the arrows.
5 min	**Follow-up to activity:** Students draw arrows to represent equal and unequal forces acting on a toy car in three separate diagrams.	• Arrows show the strength and direction of multiple forces acting on an object and can be used to predict or describe its resulting motion (or lack of motion).
5 min	**Synthesize/summarize today's lesson:** Students use science ideas about force to develop their best answers to the focus question. Then they complete a statement summarizing how they can represent forces they can't see that are acting on an object.	
1 min	**Link to next lesson:** The teacher foreshadows the next lesson in which students consider what makes objects slow down and eventually stop?	

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4 min	**Link to Previous Lesson** **Synopsis:** To review science ideas from the previous lesson, the teacher engages students in analyzing a diagram using an arrow to represent a force acting on a cart. **Main science idea(s):** • The forces acting on objects have a strength and direction that can be represented in a diagram using arrows of various lengths and directions.	Select content representations and models matched to the learning goal and engage students in their use.	**Show slides 1 and 2.** In our last lesson, you looked at some diagrams of a cart. Each diagram showed an arrow that represented the strength and direction of the force acting on the cart. Let's bring back our friend the rolling cart to help us review the science ideas we've been learning about. First, I'll draw a diagram of the cart on chart paper and use an arrow to show a force acting on the cart. **NOTE TO TEACHER:** *Alternatively, you might use one of the diagrams from the previous lesson for this review activity.* Can someone tell me what the arrow in the diagram represents? Good! What is the direction of the force in this diagram? How do you know? **NOTE TO TEACHER:** *Students should observe that the direction of the arrow shows the direction of the force.*	The arrow represents the strength and direction of the force that's acting on the cart.	

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			What does the length of an arrow represent? How strong is the force that's acting on the cart in our diagram? How do you know? **NOTE TO TEACHER:** *Students should observe that the length of the arrow shows the strength of the force exerted on the cart. A shorter arrow represents a smaller or weaker force, and a longer arrow represents a bigger or stronger force.* Now let's have a volunteer use the cart to demonstrate the strength and direction of the force that's pushing the cart. Try to match what the diagram is showing. **Volunteer demonstrates the force.** Do you think the demonstration matched the diagram? Give me a thumbs-up for yes and a thumbs-down for no. **NOTE TO TEACHER:** *Briefly discuss the diagram and demonstration as needed*	It shows how much force is acting on an object. A shorter arrow represents a small force, and a longer arrow represents a big force.	

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		Highlight key science ideas and focus question throughout.	*to reach a consensus.* **Show slide 3.** Write this important science idea in your notebooks and keep it in mind throughout the lesson: *An arrow shows both the **strength** and **direction** of a force acting on an object.*		
2 min	**Lesson Focus Question** **Synopsis:** The teacher reviews the focus question from the previous lesson: *How can we draw the forces pushing or pulling an object when we can't see them?*	Set the purpose with a focus question or goal statement.	**Show slide 4.** Today we'll continue thinking about our focus question from last time: *How can we draw the forces pushing or pulling an object when we can't see them?* **ELL support:** Review the words that describe the direction and strength of a force: *push, pull, large/strong, small/weak.* **Show slide 5.** In the previous lesson, we learned a lot about forces that act on objects, but today we'll explore some questions that are even more challenging! • What will happen if *more than one* force acts on an object at the same time? • In what direction will the object		

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			move, or will it move at all? • How can we use arrows to represent the strength and direction of the forces acting on the object?		
8 min	**Setup for Activity** **Synopsis:** Students consider what happens when more than one force acts on an object at the same time. **Main science idea(s):** • The forces acting on an object have a strength and direction that can be represented in a diagram using arrows of various lengths and directions. • Arrows pointing in different directions show that forces are acting on an object in different directions.	Ask questions to elicit student ideas and predictions. Make explicit links between science ideas and activities **before** the activity.	**Show slide 6.** First, let's return to our friend, the classroom cart. What do you think will happen if *more than one* force acts on the cart at the same time? **Turn and Talk:** Discuss your ideas with an elbow partner and be prepared to share your predictions with the class. **Whole-class share-out:** Let's hear some of your predictions. What do you think will happen if more than one force acts on the cart at the same time? **NOTE TO TEACHER:** *Invite a few students to share their ideas and predictions. Record students' predictions on chart paper for future reference, but don't discuss them at this time.*	I think the cart will move in different directions. I don't think the cart will move at all! I think the cart will move in the direction that the stronger force is	

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		Ask questions to elicit student ideas and predictions.	How might more than one force act on the cart at the same time? How might we represent that? What do you think will happen if the forces are the same? What do you think will happen if one force is stronger than the other force? Let's see whether your predictions match what actually happens. I need two volunteers to come up and demonstrate two forces *pulling* the cart. Student 1, I'd like you to stand on one side of the cart, and Student 2, I'd like you to stand on the other side of the cart. Get ready to *pull* the cart in opposite directions when I give you the signal. For now, just think about the *direction* of each force, not the strength. In which direction do you think Student 1 will exert a force on the cart? How can	pushing it. Well, two students could push the cart at the same time. We could use two arrows to show two forces. I don't think anything will happen. The cart will move.	

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			we represent that on a diagram? **NOTE TO TEACHER:** *Draw a diagram on chart paper that reflects student predictions about the direction of each force pulling the cart.* In which direction do you think Student 2 will exert a force on the cart? How could we represent that force? What do you think will happen when Students 1 and 2 pull on the cart?	I think Student 1 will pull the cart toward *[the window, the wall, the whiteboard, the back of the room]*. We could represent this by pointing an arrow in that direction. I think Student 2 will pull the cart toward *[the door, the window, the wall, the whiteboard, the back of the room]*. We could represent this by pointing an arrow in that direction. It depends on how hard each of them pulls the cart! If one of them pulls harder than the other, the cart will move in the direction of the stronger force.	

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			Let's see what happens! Student 1 and Student 2, on my signal, pull gently on the cart with the *same* amount of force. How will you know whether you're pulling with the same amount of force? OK, ready, set, pull! Thank you, Students 1 and 2! You may return to your seats.	I disagree. If they pull on the cart at the same time, the cart won't move at all. Well, if the same amount of force is pulling in opposite directions, the cart will just stay still. If the cart doesn't move, we'll know we're pulling with the same force. But if the cart moves, we'll know that one of us is using more force than the other.	If forces are being exerted on the cart, why wouldn't it move?

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		Ask questions to elicit student ideas and predictions.	**Whole-class share-out:** So what happened to the cart? Is this what you predicted? Now I need two new volunteers. **Turn and Talk:** What do you predict will happen if Student 3 pushes the cart with a *gentle* force, and Student 4 pushes with a *stronger* force? Discuss your predictions with your elbow partner. **Whole-class share-out:** Let's hear some of your predictions. What do you think will happen to the cart if Student 3 uses a stronger force than Student 4? How could we represent these different forces with our arrows? **NOTE TO TEACHER:** *Draw a diagram on chart paper that reflects student predictions about the two unequal forces acting on the cart. Alternatively, ask Students 3 and 4 to select the foam*	I think the cart will move a little bit. We could use a longer arrow to represent the stronger force and a shorter arrow to represent the weaker force.	Tell us more about your thinking.

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			arrows they'd use to represent a gentle force and a strong force. OK, Students 3 and 4, get ready to push the cart in opposite directions using different forces. Remember, Student 3 is using a gentle force, and Student 4 is using a strong force. Ready, set, push! Thank you, Students 3 and 4! You can return to your seats. **Whole-class discussion:** What happened to the cart? Is this what you predicted? Let's look at the arrows again. Why do you think the cart moved in the direction Student 4 was pushing? How do the arrows represent *both* the strength and direction of the forces acting on the cart?	The cart moved in the direction Student 4 was pushing because a stronger force was used. This is more confusing. The two arrows represent forces acting in	Can anyone add to this idea?

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			Great job, everyone! Next, we'll apply these important science ideas about force and motion to a different object—a small toy car.	opposite directions with two different strengths, and the stronger force wins!	What do you mean by "wins"?
15 min	**Activity** **Synopsis:** Students use toy cars and paper arrows to represent multiple forces acting on an object. They use the arrows to show the direction and strength of the forces and the resulting movement of the cars. **Main science idea(s):** • The forces acting on an object have a strength and direction that can be represented in a diagram using arrows of various lengths and directions. • The length of an arrow represents the relative	Select content representations and models matched to the learning goal and engage students in their use. Engage students in using and applying new science ideas in a variety of ways and contexts.	**NOTE TO TEACHER:** *Have students pair up with an elbow partner. Then distribute one toy car and one envelope containing six paper arrows of varying lengths to each pair.* **Show slide 7.** Before we begin our investigation, let's practice working with forces of different strengths and using an arrow to represent the strength and direction of a force acting on an object. **NOTE TO TEACHER:** *Limit this review to no more than 5 minutes, or skip it if you feel your students understand the concepts they'll be applying in the investigation.* **Turn and Talk:** Take turns exerting a different force on the toy car one at a		

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	strength of the force exerted on an object. • The direction of an arrow represents the direction of the force acting on an object. Arrows pointing in different directions show that forces are acting on an object in different directions. • If more than one force is acting on an object, we can predict the object's motion and the relative strength of the forces by comparing the lengths of the arrows.		time. First exert a small, gentle force; then exert a medium force; and finally, exert a big, strong force. Then discuss these questions with your partner: • What happened when you used a small, medium, or big force on the toy car? What differences did you observe in the car's motion? • How can you use your arrows to show the *direction* of the force on the car? • How can you use your arrows to show the *strength* of the force on the car? **NOTE TO TEACHER:** *Circulate among the pairs during this activity and make sure they understand how to apply the ideas related to the direction and strength of a force. Note any confusion or misconceptions that need to be addressed.* **Whole-class share-out:** So what happened when you exerted different forces on the car? What did you notice about the car's motion?	The car went farther when we pushed harder.	Was that the only difference you noticed about the car's motion when you pushed

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					harder and softer?
				We noticed that the car went faster when we pushed harder.	Who can compare the motion of the car when you exerted stronger and weaker forces?
				When we used a stronger force, the car moved farther and faster. When we used a softer force, it moved slower and not as far.	
			That's interesting! With the cart, we didn't notice the speed or distance it traveled when we exerted a stronger force. But with the car, we discovered that the strength of a force affects the speed of an object and how far it moves. **Show slide 8.**		
		Ask questions to elicit student ideas and predictions.	**Turn and Talk:** What do you predict will happen when you and your partner exert forces of the *same*, or *equal*, strength on the toy car at the *same* time? Share your predictions with your partner. **ELL support:** ELL students will benefit from articulating their predictions aloud,		

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			so make sure to allow enough time for the Turn and Talk. Let's find out what happens with the car and compare the results with what happened with the cart. When I give the signal, I want you and your partner to push the toy car with the same force at the same moment. How will you know whether the forces you're exerting on the car are the same? OK, get ready. Push! **NOTE TO TEACHER:** *Give pairs a few seconds to exert equal but opposite forces on the car.* **Whole-class share-out:** What happened when you pushed on the car with the same, or equal, force? Let's hear some of your observations. **Show slide 9.** **Turn and Talk:** Now talk with your partner about how you can use the paper arrows in your envelope to represent the same, or equal, forces you exerted on the toy car.	The car won't move.	

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			• Which arrows best represent the strength and direction of the forces both of you exerted on the car? • Where will you place the arrows? • Should the arrows touch the car? When you've made these decisions, use the arrows you selected to show the forces you and your partner used on the car. Make sure to show both the strength and direction of the forces. **NOTE TO TEACHER:** *Remind students that two objects must touch for one object to exert a force on the other object.* **Show slide 10.** What do you think will happen when you and your partner exert forces of *different*, or *unequal*, strength on the toy car at the same time? **Turn and Talk:** Share your predictions with your partner and then decide who will push or pull the car with a small, gentle force and who will push or pull it with a big, strong force. OK, let's find out what happens! How will you know whether the forces you're exerting on the car are different?	The car will move!	

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			NOTE TO TEACHER: *Give pairs a few seconds to exert unequal and opposite forces on the car.* **Show slide 11.** **Turn and Talk:** Now discuss with your partner how you can use your arrows to represent the unequal forces you exerted on the car. • Which arrows best represent the strength and direction of the forces both of you exerted on the car? • Where will you place the arrows? When you've made these decisions, use the arrows you selected to show the forces you used on the car. Make sure to show both the strength and direction of the forces. **Whole-class discussion:** Let's have one pair come up and show us how you used your arrows to represent the *unequal* forces you exerted on the car. Also describe what happened with the car's motion. In what direction did the car move? Did it move in the direction of the shorter or longer arrow?		

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5 min	**Follow-Up to Activity** **Synopsis:** Students draw arrows to represent equal and unequal forces acting on a toy car in three separate diagrams. **Main science idea(s):** • Arrows show the strength and directions of multiple forces acting on an object and can be used to predict or describe its resulting motion (or lack of motion).	Make explicit links between science ideas and activities **after** the activity. Engage students in using and applying new science ideas in a variety of ways and contexts. Select content representations and models matched to the learning goal and engage students in their use.	Now let's see how much you've learned about forces in this lesson! **NOTE TO TEACHER:** *Distribute handout 2.1 (What Are the Forces?) and go over the directions and diagrams with students.* **Show slide 12.** ***Embedded Assessment Task*** This handout shows three different diagrams of a toy car. For the first diagram, you'll draw one arrow showing the force that acts on the car to get it moving. For the other diagrams, you'll draw two arrows representing the equal or unequal forces two people exert on the car. You'll work on your own to complete this handout using science ideas about forces and motion. Any questions before we begin? **NOTE TO TEACHER:** *Circulate around the room as students work on their diagrams and answer questions as needed. Ask elicit and probe questions to reveal student thinking and note any*		

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			misconceptions or confusion that needs to be addressed.		
5 min	**Synthesize/Summarize Today's Lesson** **Synopsis:** Students use science ideas about force to develop their best answers to the focus question. Then they complete a statement summarizing how they can represent forces they can't see that are acting on an object.	Highlight key science ideas and focus question throughout. Engage students in making connections by synthesizing and summarizing key science ideas.	**Show slide 13.** Our focus question is *How can we draw the forces pushing or pulling an object when we can't see them?* **Turn and Talk:** Discuss this question with an elbow partner and come up with your best answer using science ideas about forces. Think about how we represented forces like scientists in our investigations today. Then complete the sentence on the slide in your science notebooks: *I can't see the forces pushing and pulling an object, but I can represent them like scientists do by* _____. **Optional summary (if time allows):** In your science notebooks, find the pictures you drew in lesson 1b that show what makes something start to move. Add arrows to your pictures to represent the strength and direction of the forces acting on your object. **Whole-class share-out:** Let's hear how a few of you completed the sentence on the		

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			slide. How can we show forces we can't see that are acting on an object?		
1 min	**Link to Next Lesson** **Synopsis:** The teacher foreshadows the next lesson in which students consider what makes objects slow down and eventually stop?	Link science ideas to other science ideas.	**Show slide 14.** So far in this unit, we've explored how one or more forces can make an object start to move and how we can use arrows to represent the strength and direction of these forces. Next time, we'll think about what makes objects slow down and eventually stop.		