SCALE

Subunit 1: Contact Forces
Student Book

Unit Essential Question: How can we change the motion of an asteroid heading toward Earth?

Subunit Essential Question: How can we change the motion of an object by using a contact force?

EXPLAIN 1

In the Engage lesson, you explored the idea that we can change the motion of an object by pushing or pulling on it. How are pushes and pulls related to motion, and how can we use this information to prevent an asteroid from hitting Earth? To help you answer this question, you will read an article on Newton's first law of motion.

Part 1: Close-Reading Protocol: Newton's First Law of Motion

1. To help you answer the Subunit Essential Question above, you will read an article titled "Newton's First Law of Motion."

2. **Purpose of reading the article**

   The article will help you answer the following questions:

   a. What is motion and how do we describe it?

   b. What are forces and how do we describe them?

   c. How do unbalanced and balanced forces affect the motion of an object?

   d. What is Newton's first law of motion and what does it explain?

3. **First read: Read independently**

   a. **Read with a pencil**: As you read, **annotate** the text.

   b. Following are some ideas for how to annotate.

Mark It Up!

Left Margin	**Right Margin**
● What is the author saying? ○ Summarize a selected amount of text. **Highlight** key information (use sparingly) ● Main idea ● Claims ● Relevant data/evidence ● Significant phrases **Underline** words, phrases, or sentences that are unclear or stand out to you. **Circle** known words used in unfamiliar ways. **Symbols:** You can use some symbols to save time. Make sure you know what your symbols mean. For example: ● Question mark (?) = I have a question about this. ● Asterisk (*) = This idea is new to me. ● Check mark (✓) = I knew this.	● Questions ● Comments ● Connections ● Directions

4. **Partner talk**
   a. Turn to a partner to discuss the article.
   b. Use these sentence starters/frames if you have trouble getting started:
      i. A word or phrase I [did not know / found confusing / found interesting] is _____ because _____.
      ii. One pattern I noticed is _____.
      iii. I think the author wants me to know _____.
5. **Class discussion 1**
   a. Share the ideas that you and your partner discussed.
   b. Share words or phrases that were unfamiliar or unclear, and explain how you and your partner

tried to figure out their meaning.

6. **Second read: Read for understanding**
   a. Read the article again.
      i. Try to find the answers to the questions you still have.
      ii. Identify any additional questions.

7. **Answer questions using the Listening Triads Role Cards** *(see questions below the article)*
   a. Answer the questions that follow the “newton’s First Law of Motion” article using the Talker, Questioner, and Listener roles that you used previously.
   b. Review the Listening Triads Role Cards.
   c. Decide who will be the first Talker, Questioner, and Listener.
   d. The Talker will share ideas about one of the questions. The Questioner can ask the Talker questions to clarify. The Listener should record the answers.
   e. Switch roles after each question.

8. **Class discussion 2**
   a. Share any new understanding from your group discussion.

Listening Triads Role Cards

TALKER

Your role is to express your ideas, arguments, or evidence to your group members.

- My reason for saying that is...
- Because...
- I have noticed that...
- I see it differently...
- If...
- What if...?
- Why?
- I have a suggestion...
- I think...because...
- I know...

LISTENER

Your role is to listen carefully to what is being said by the Talker and Questioner and record what you think are the main points being made, any questions asked, and/or evidence presented in the conversation between the Talker and Questioner. You must be silent during the conversation.

QUESTIONER

Your role is to ask the Talker questions that encourage them to elaborate, give evidence, and clarify.

- What do you think?
- Why do you think that?
- Let's think again...
- Can you say a bit more?
- What else do we know?
- I can tell you about...
- Can you explain?
- I hadn't thought of that until you said...
- I disagree because...
- But...
- I agree but...
- I believe that...
- I think...
- A different point of view would be...
- I can't see how your point fits in with...

Listening Triad Role Cards adapted from a Strategic Education Research Partnership Assessment Strategy, 2009; Role Cards developed by Lisa Ernst, Alice Fong Yu Alternative School, San Francisco Unified School District

Newton's First Law of Motion

Section 1: Defining Motion

People move and observe objects in motion every day. What exactly does it mean when we say something is in motion? **Motion** can be defined as a change in **position.** When an object moves its position, or location, changes. We can tell that an object is moving when the distance from that object to another object—usually one that is not moving—is changing. For example, if you walk past a table, the **distance** between you and the table changes. Below are photographs of objects that were in motion when the images were taken. How can you tell objects were moving when the pictures were taken? What reference points can you use?







Changing Position

We can tell if an object is moving by comparing the object to something else, called a **reference point**. The person on the bicycle in the photographs above can use the buildings or lines on the road as reference points. Those items are stationary (not moving or "at rest") from the point of view of the person on the bicycle. It can be more difficult to tell if something is moving by comparing it with another object that is moving. In the photograph with the bicycle, the car is also moving, but it is not as easy to tell if you only compare the car with the person on the bicycle.

Determining if something is moving also depends on what is called a **frame of reference**. Imagine that a bus passes by as you stand on the sidewalk. It may be obvious to you (from your frame of reference) that the bus is moving. From the point of view of a passenger, the bus is not moving, and neither are the people on the bus. If the ride were really smooth and quiet, the people may only be able to tell that the bus is moving by looking at something outside the bus. It would be easier for them to look at a reference point, such as you, or something else that the bus moves past.

Section 1 Summary

- Motion is defined as a change of position.
- We can tell if something is moving by comparing it with a reference point.

Section 1 Reflection Question

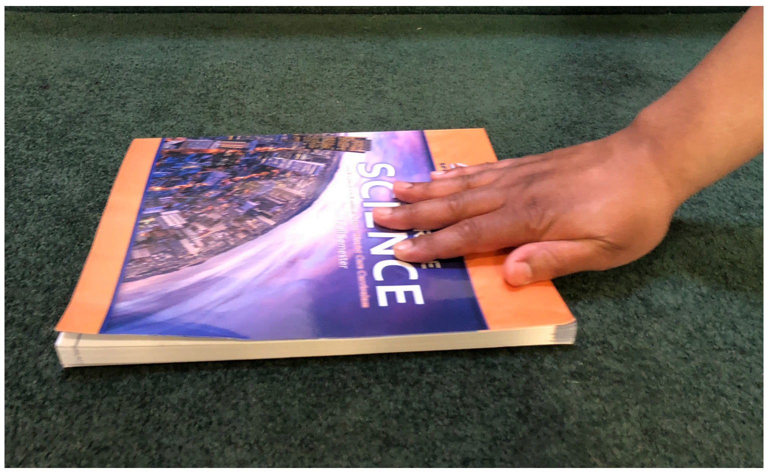
1. From your seat, look at your classroom, a window, or a doorway. Select an object that is in motion. What reference point helped you determine that the object was moving?

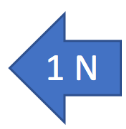
Section 2: Forces and Motion

All changes in motion are caused by forces. A **force** can be defined as a push or a pull that is exerted on an object by another object. A force always happens as an interaction between two objects. Every time the motion of an object changes, it is because a net force has been exerted on it. A force can cause an object at rest to start moving or a moving object to change its speed, direction, or both.

So far you have been exploring **contact forces,** or forces that occur when objects are touching. When this happens we say that the objects are in physical contact. The person in the photo below was able to get the book to move to the left by applying force with a hand. The objects that were in contact when the book started to move were the person's hand and the book. We say that the person applied force to the book to move it.

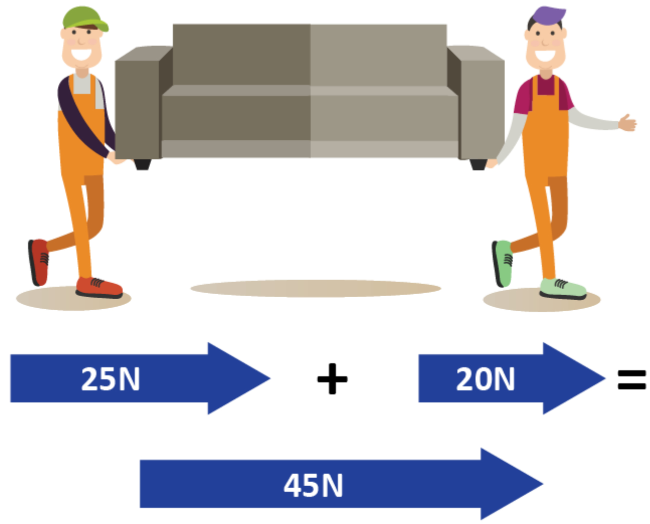
Some forces are stronger than others. If you apply a small amount of force to a book on a table, the force will change its motion. If you push the book with a large amount of force, it will move faster and farther. The amount or strength of a force is called the **magnitude** of the force. The unit of measurement for the magnitude of a force is a **newton (N)**. A newton is the force needed to cause a mass of 1 kilogram to accelerate at 1 m/s^2. A Newton equals 1 kg • m/s^2. The newton was named for the scientist Isaac Newton, who is famous for his laws of motion.





A force is also described by the direction in which it acts. In the photo, the person is applying a 1 N force on the book to the left, represented by the blue arrow below. The magnitude and direction of a force can be described using arrows, called **vectors**. The length of the arrow represents the magnitude of the force, and the arrow points in the direction that the force is applied. If the strength of one force is greater than another, we use a longer arrow to show the difference in magnitude.

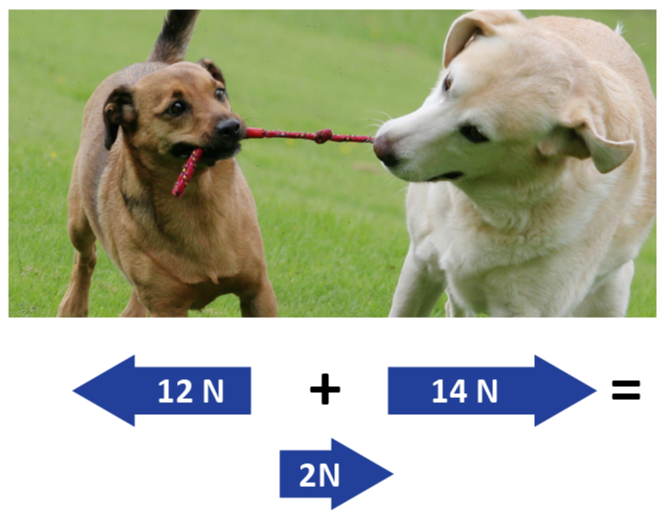
Forces Acting in the Same Direction
The net force acting on an object is the combination of all the individual forces acting on it. In general, if two forces act on an object in the same direction, the **net force** is equal to the sum of the two forces. This results in a force with a greater magnitude than either of the individual forces alone.



In the figure, the man on the left pushes the couch to the right with a force of 25 Newtons. The man on the right pulls the couch to the right with a force of 20 N. Notice that the arrow for 20 N is shorter than the arrow for 25 N. Both arrows indicate that the direction of the force is to the right. Because these forces are acting in the same direction, the total amount or net force is equal to 45 N, to the right. Since there are no forces in the other direction, the couch will move to the right.

Forces Acting in Opposite Directions

Balanced Forces: If the opposing forces are **equal,** or **balanced**, the **net force is zero** and the motion of the object does not change. This is true whether the object is at rest or moving. When an object is not moving, all the forces acting on it are balanced. If an object is moving at a constant speed, in a straight line, all the forces acting on it are also balanced.

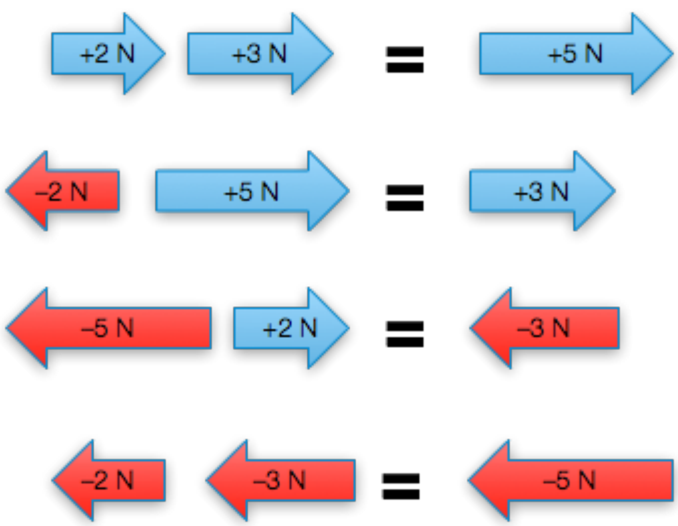


Unbalanced Forces: If the opposing forces are **unbalanced**, the **net force is not zero**. The net force is less than either of the individual forces. When unbalanced forces are applied to an object, the object will move in the same direction as the net force.

In the image, the book is at rest, that is, at the beginning, it's not moving. Then the two dogs start pulling the rope in opposite directions. One dog pulls with more force than the other. The net force acting on the rope is 2 N to the right, so the rope will move to the right.

Negative Forces?

When you combine forces, sometimes it helps to treat forces as *positive* or *negative*. Usually, we count a force moving to the right as positive and to the left as negative. That way, when you combine forces—whether they are in the same direction or in opposite directions—the rule is simply to add up the forces.



Section 2 Summary

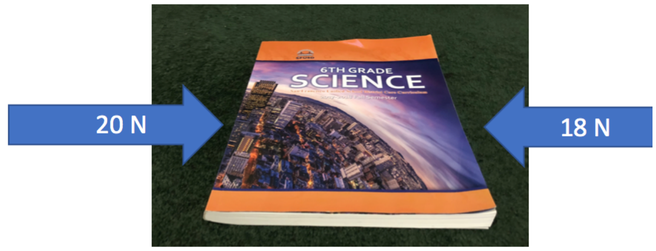
- The net force acting on an object is the combination of all of the individual forces acting on it.
- An object's motion will change in the direction of the net force.
- If two forces act on an object in the same direction, the **net force** is equal to the sum of the two forces. This results in a force with a greater magnitude than either of the individual forces alone.
- If two forces act on an object in opposite directions, this results in a force with a smaller magnitude than either of the opposing forces.
  - If the opposing forces are **equal,** or **balanced**, the **net force is zero** and the motion of the object does not change.
  - If the opposing forces are **unbalanced,** the **net force is not zero**. The magnitude of the net force is less than that of either of the individual forces, and the motion of the object changes in the direction of the net force.

Section 2 Reflection Questions

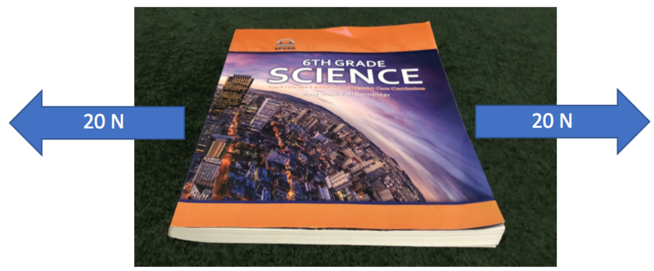
1. What is meant by the net force that acts on an object?

2. If an object has two forces acting on it, how can the net force be zero?

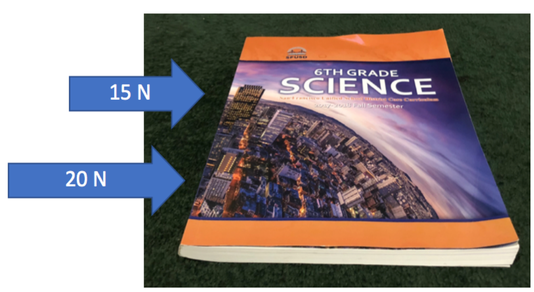
3. Imagine that the book in the photo on the right is at rest, and then two people start pushing on it in opposite directions. The amount of force exerted by each person is shown in the arrows.
    a. Draw a diagram with arrows that shows the two opposing forces and the net force acting on the book.
    b. What is the net force on the book?
    c. WIll the book move? If so, in what direction?
    d. Will the speed of the book increase, decrease, or remain the same?



4. Imagine that the book in the photo on the right is at rest, and two people start pulling on it in opposite directions. The amount of force exerted by each person is shown in the arrows.
    a. Draw a diagram with arrows that shows the two opposing forces and the net force acting on the book.
    b. What is the net force on the book?
    c. WIll the book move? If so, in what direction?
    d. Will the speed of the book increase, decrease, or remain the same?



5. Imagine that the book in the photo on the right is at rest, and two people start pushing on it in the same direction. The amount of force exerted by each person is shown in the arrows.
    a. Draw a diagram with arrows that shows the two individual forces and the net force acting on the book.
    b. What is the net force on the book?
    c. WIll the book move? If so, in what direction?



d. Will the speed of the book increase, decrease, or remain the same?

6. The ball in the illustration below is at rest. The people in the illustration are about to kick the ball in opposite directions. The force of each kick is indicated in the arrows.
   a. Draw a diagram with arrows that shows the opposing and net force acting on the ball when it is kicked. (You only need to draw the ball and the arrows).
   b. What will be the net force on the ball?
   c. Will the ball move? If so, in what direction will it move?
   d. Will the speed of the ball increase, decrease, or remain the same?

Section 3: Newton's First Law of Motion

Newton's first law of motion states that an object at rest will remain at rest and an object in motion will continue moving in a straight line, at a constant speed, in the same direction, unless an unbalanced net force acts on it. The tendency for an object to resist a change in motion is called **inertia.**

The mass of an object is related to inertia. Objects with greater mass tend to resist changes in motion more than objects with less mass. Imagine that you want to move one book at rest on a table by pushing on it with your hand. According to Newton's first law, the book at rest tends to resist a change in motion. You could apply a net force with your hand to push the book across the table. Now imagine a box that contains 100 copies of the same book. This box of books resists changes in motion more than the single book does. Newton's first law also applies to objects that are in motion. It would be easier for you to stop a small toy car moving toward you at a constant speed than a real car moving toward you at the same speed. The real car resists changes in its motion more than the toy car does.

The Force of Friction

On Earth, it may seem that constant motion is not possible. Eventually all moving objects on Earth slow down and come to a stop. However, when any object is moving, the only way for it to speed up, slow down, or come to a stop is for an unbalanced force to be applied. The force that occurs when two objects are sliding past one another has a special name. This force is call the force of **friction**. Friction is caused by the tiny bumps and irregularities of the surface of one object interacting with the tiny bumps and irregularities of the surface of another object. Some surfaces are smoother than others. Smooth surfaces produce less frictional force than rough surfaces. When a hockey puck moves on ice, there is less friction acting on it than when it moves on a surface that is more rough, like a carpeted floor. The magnitude of the force of friction depends on the types of matter in contact and how closely the matter is pressed against another piece of matter. The force of this kind of friction does not depend on the speed of the motion of the objects.

The force of friction always acts in the opposite direction of the motion. On Earth, when a moving object slows down and comes to a stop, this is often because an unbalanced force of friction is acting on the object. When an object is moving in space, it does not come into contact with other surfaces of objects as much. It is easier to observe evidence of Newton's first law of motion in space, where the force of friction is almost zero. In the simulations, you were instructed to set the force of friction to "none" to get a better idea of how motion changes when the force of friction is not present. The experiments would have been a bit different if we had also modeled the force of friction acting on them.

Section 3 Summary

- Newton's first law of motion states that an object at rest will remain at rest and an object in motion will continue moving in a straight line, at a constant speed, in the same direction, unless an unbalanced net force acts on it.
- The tendency for an object to resist changes in motion is called inertia.
- Mass is related to inertia. Objects with more mass tend to resist changes in motion more than objects with less mass.

Section 3 Reflection Questions:

1. If an object is at rest, how can you change its motion?

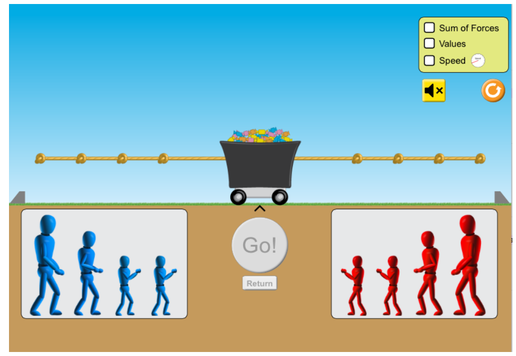
2. If an object is moving, how can you change its motion?

3. If the net force acting on an object is equal to zero newtons, is it moving or at rest? Explain.

4. If an object is moving at a constant speed in a straight line, what must happen for it to change direction?

5. How might Newton's first law relate to an asteroid that is heading toward Earth?

Part 2: Explaining the Basics of Motion



1. Click to open the PhET Forces and Motion: Basics simulation (https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html). Select "Net Force" at the beginning, not "Motion," "Friction," or "Acceleration." This should open a screen like the one shown.

2. Work together in your group to write up the set of procedures you are assigned.

3. Share your procedures and explanations with another group to help you revise. Revise your procedures based on the feedback you receive.

- **Procedure A:** Write up a procedure that shows how to increase the speed of the cart from when it is at rest. Explain the reasons why the motion changes using the concept of net force and Newton's first law of motion.

- **Procedure B:** Write a procedure that makes the cart move at a constant speed. Explain the reasons why the motion changes using the concept of net force and Newton's first law of motion.

- **Procedure C:** Write a procedure that allows you to slow down a cart that is already moving without using the gray stopper blocks. Explain the reasons why the motion changes using the concept of net force and Newton's first law of motion.

- **Procedure D:** Write a procedure that allows you to change the direction of a cart that is already moving without using the gray stopper blocks. Explain the reasons why the motion changes using the concept of net force and Newton's first law of motion.