AmplifyScience

Force and Motion:

Docking Failure in Space

Investigation Notebook with Article Compilation

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Force and Motion:

Docking Failure in Space

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

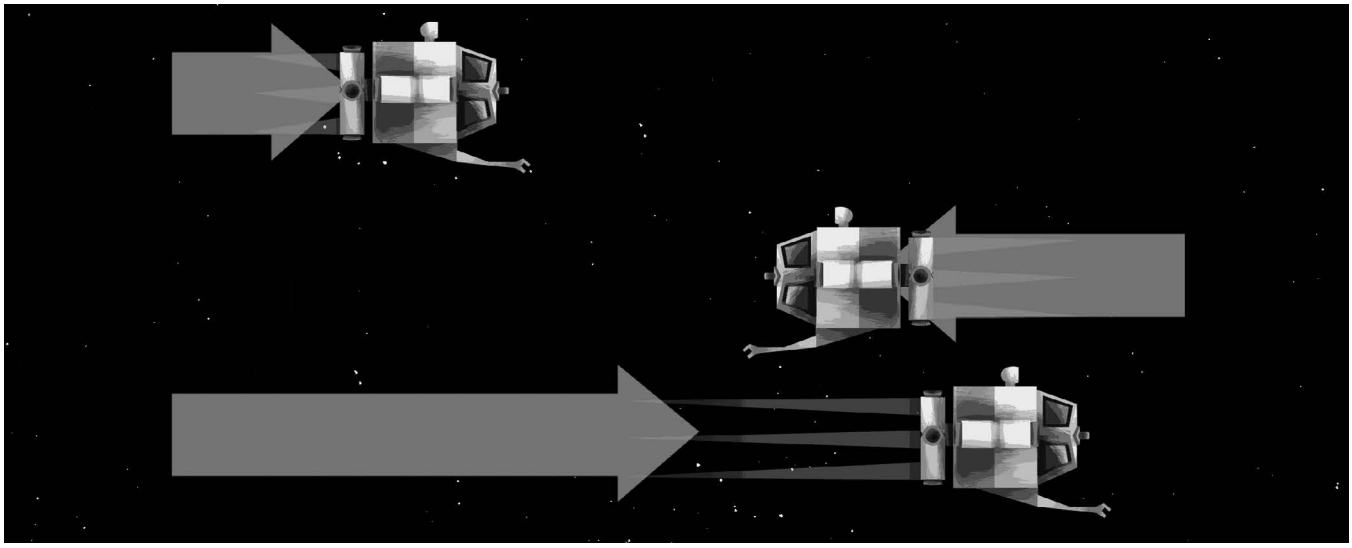
Force and Motion: Docking Failure in Space
Unit Overview

In this unit, you are a student physicist working at the Universal Space Agency (USA). You are investigating why a routine mission in which an asteroid-collecting pod was supposed to deliver samples to a space station did not go as planned. During other missions, pods successfully dock with the space station and deliver their samples. On this mission, however, the pod failed to dock and ended up traveling in the opposite direction, *away* from the space station. In the command center of the space agency, the video signal was lost seconds before the pod was supposed to dock, so scientists and engineers are struggling to explain what happened. Your job is to reconstruct those missing seconds and explain why the pod failed to dock. In order to solve this mystery, you will need to learn about the science of force and motion and apply what you learn to the situation. Looking ahead to the end of the unit, you will use your knowledge about force and motion to help a film student create a dramatic collision scene on a miniature movie set.

Name: _____ Date: _____

Chapter 1: Force and Velocity
Chapter Overview

The Universal Space Agency lost contact with an asteroid collection pod for a few seconds just before it was scheduled to dock with a space station. Once the space agency regained contact, they found that the pod was moving away from the station. Why did the pod start moving away instead of docking? You will begin your investigation by exploring the relationship between force and motion, looking for evidence about how forces can cause changes in motion.



Name: _____ Date: _____

Lesson 1.2: Describing Changes in Motion

Welcome, student physicists! Today you will learn about the Universal Space Agency's most recent Asteroid Collection Mission (ACM), which did not go as planned. You will start working together to figure out what happened to the ACM pod during the time it lost contact with Mission Control on the ground. You will begin your investigation by using physical materials to observe and describe changes in motion. How can an object's motion change? Let's find out!

Unit Question

- How do forces affect motion?

Chapter 1 Question

- What caused the pod to change direction?

Vocabulary

- velocity

Name: _____ Date: _____

Warm-Up

1. **How can the motion of an object that is already moving change?**

   An object that is already moving can . . .

   _____

   _____

   _____

   _____

2. **How can the motion of an object that is NOT moving change?**

   An object that is not already moving can . . .

   _____

   _____

   _____

   _____

Name: _____ Date: _____

Discussing What Happened to the Pod

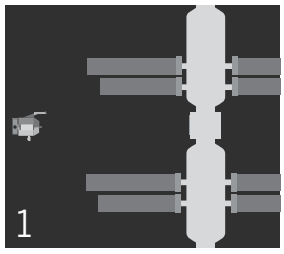
What happened during those seconds when the space agency lost contact with the pod?

1. Read the claims carefully.
2. Study the storyboard.
3. Discuss the claims with your partner. Which claim makes the most sense to you?

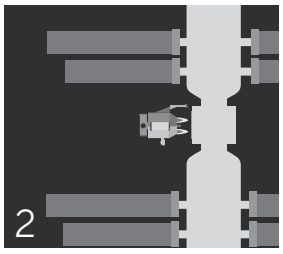
Normally, when the thrusters fire, the pod will stop, but this mission was different.

Claim 1: The thrusters caused the pod to move in the opposite direction.

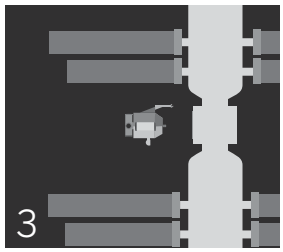
Claim 2: The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction.



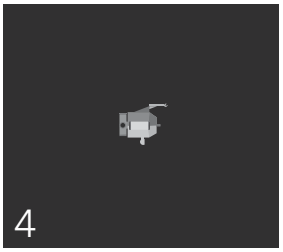
Pod approaches space station at medium speed.



Thrusters fire to stop the pod.



Thrusters cause pod to move in opposite direction OR pod hits space station and bounces off.

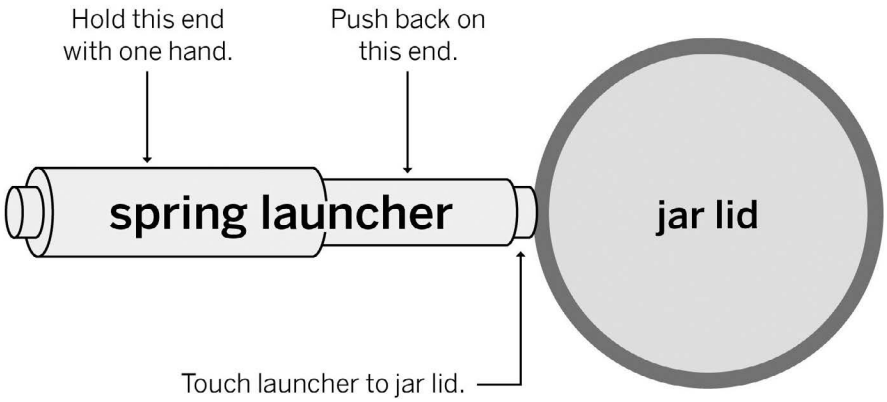


Pod travels far away from the space station.

Name: _____ Date: _____

Exploring Changes in Motion

Top View of Launcher Setup



Use the materials on your tray to investigate the guiding question. Record your notes in the table. One possible answer has been provided to help you get started.

Note: You are not required to use the spring launcher for every trial, but when you do, be sure it's only at mark ***1***.

Guiding Question: *In what ways can the motion of an object change?*

- An object that is already moving can . . .
- An object that is not already moving can . . .

Example: An object that is already moving can slow down.

Name: _____ Date: _____

Discussing Changes in Motion

What are the five ways an object's motion can change?

Use what you learned in today's activity and discuss this question with a partner. Put your ideas in a list. One response has been filled in to help you get started.

1. start moving

2. _____

3. _____

4. _____

5. _____

Name: _____ Date: _____

Lesson 1.3: Investigating Direction of Force

A digital simulation will help you investigate what happened to the ACM pod during the time when the video signal went out. You will use the *Force and Motion* Simulation to investigate what can cause an object, such as the ACM pod, to change velocity.

Unit Question

- How do forces affect motion?

Chapter 1 Question

- What caused the pod to change direction?

Vocabulary

- cause
- effect
- exert
- force
- velocity

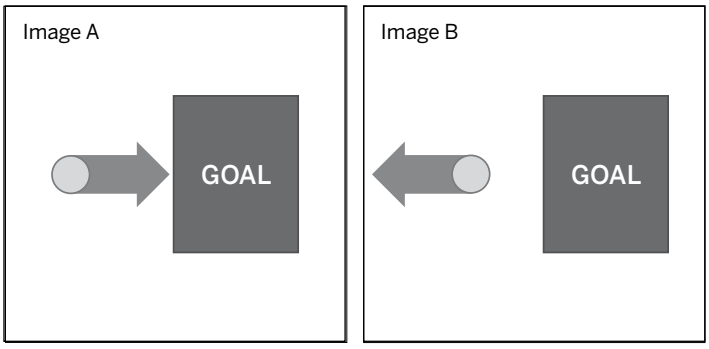
Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Sorting Tool activity: Cause and Effect

Name: _____ Date: _____

Warm-Up

1. Look carefully at the pair of images and think about what the arrows mean.



Which image above shows the direction someone would need to kick the ball in order to move it toward the goal ? (check one)

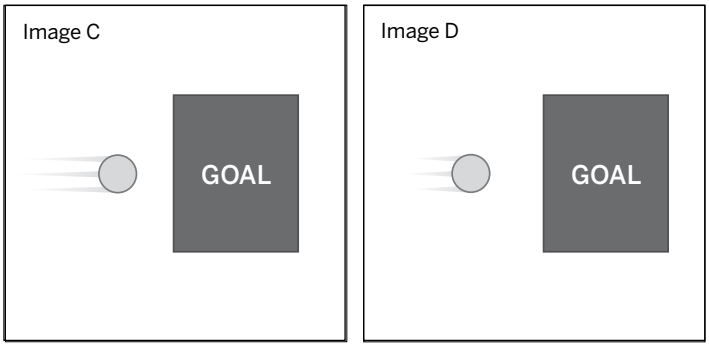
☐ Image A ☐ Image B

Explain your answer.

_____

_____

2. Look carefully at the pair of images below and think about what the group of three lines attached to each circle might mean.



Which image shows a faster-moving ball? (check one)

☐ Image C ☐ Image D

Explain your answer.

_____

_____

Name: _____ Date: _____

Gathering Evidence About Velocity Changes

Part 1: Gathering Evidence About Changes in Velocity

1. Use the *Force and Motion* Simulation to discover what you need to do to change an object's velocity.
2. Your teacher will demonstrate the first change, and then each member of your group will explore one of the four remaining changes.

Object's velocity change	**How you made this change**
1. start moving	
2. speed up	
3. slow down	
4. stop moving	
5. move in opposite direction	

Part 2: Gathering More Evidence About Velocity

1. Use the *Force and Motion* Simulation to determine how to exert a force to cause an object's velocity to change in each of the five ways.
2. Predict the direction a force must be exerted. Use one of these options:
   - **same** direction as object's motion
   - **opposite** direction as object's motion
   - **any** direction
3. With your partner, test your predictions and record the results in the third column.
4. Discuss the Investigation Question with your partner: *What makes an object's motion change?*

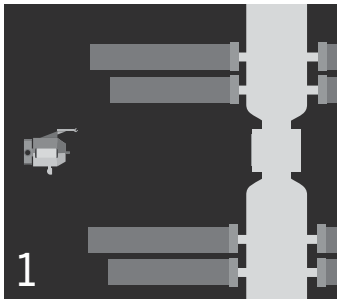
Object's velocity change	**Direction of force (predicted)**	**Direction of force (actual)**
1. start moving		
2. speed up		
3. slow down		
4. stop moving		
5. move in opposite direction		

Name: _____ Date: _____

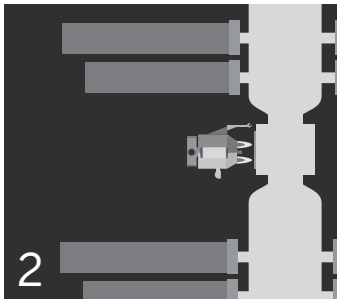
How the Pod Changed Its Velocity

1. Refer to the series of images for Asteroid Collection Missions.
2. Circle the bold phrase that completes the sentence to indicate the direction of the force required to stop the pod.

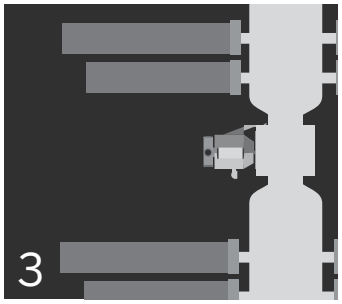
Asteroid Collection Missions



Pod approaches space station at medium speed.



Thrusters fire to stop the pod.



Docking: pod connects to space station.

The thrusters fire to exert a force in the (**same direction** | **opposite direction**) as the motion of the pod, and that causes it to stop.

Name: _____ Date: _____

Homework: Identifying Cause and Effect

1. Open the *Force and Motion* Sorting Tool activity: Cause and Effect.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Identify the direction of the force that will cause each change in velocity.

Do: Drag each card to the appropriate column.

Name: _____ Date: _____

Lesson 1.4: Explaining Force and Velocity

A fictional character, Sherman, needs your help in understanding the difference between *force* and *velocity* when describing a baseball's motion. Get ready to explain the difference between these two terms! Next, you will work together in groups to explain how forces can cause different changes in velocity with another baseball-related situation. Afterward, you will further examine how forces can affect an object's motion with a hands-on activity.

Unit Question

- How do forces affect motion?

Chapter 1 Question

- What caused the pod to change direction?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.

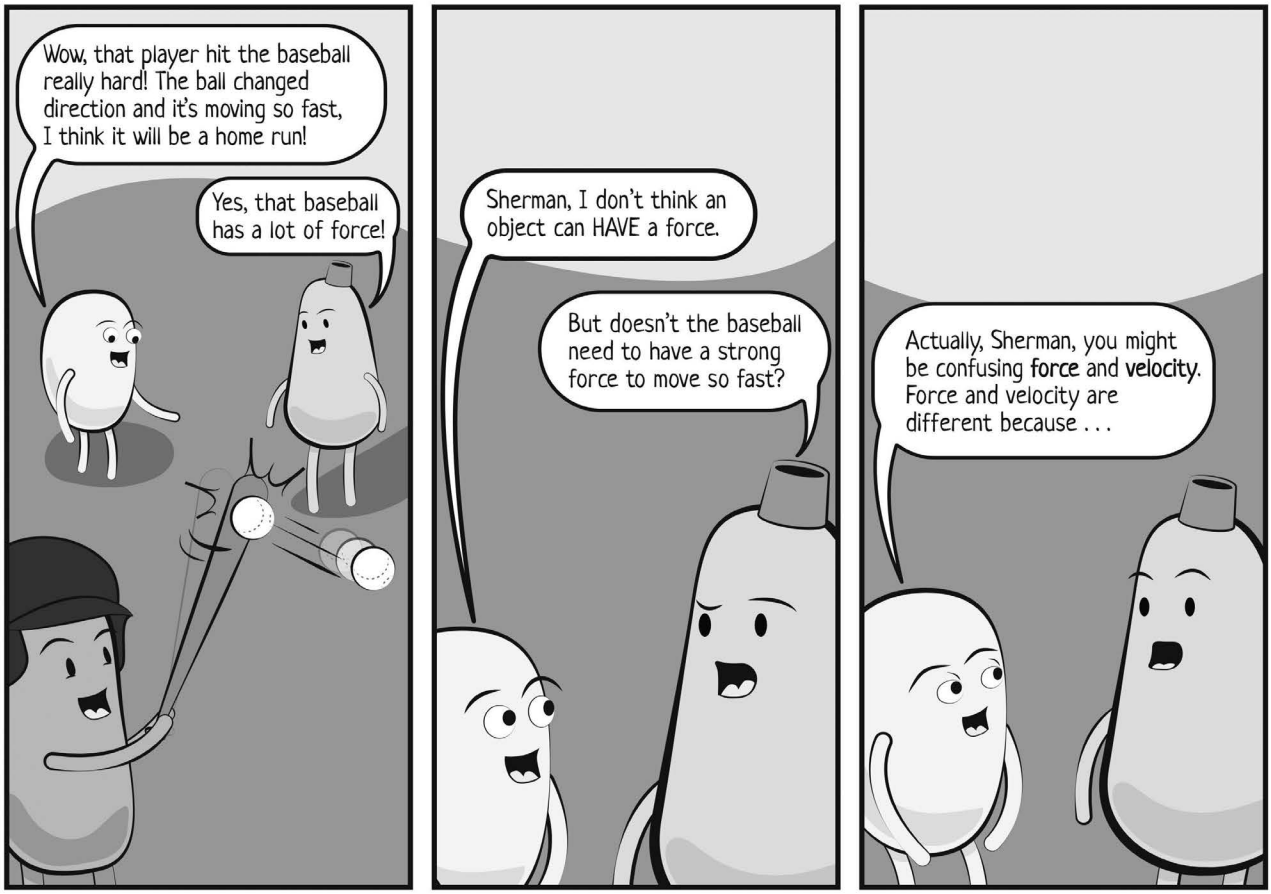
Vocabulary

- cause
- effect
- exert
- force
- velocity

Name: _____ Date: _____

Warm-Up

Sherman's Story: Force and Velocity



How would you finish the last sentence? What would you say to Sherman so he understands that *velocity* and *force* are different? Write a response and be prepared to share it with a partner.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Word Relationships

1. Imagine this scene:

   Mary used a bat to swing at a baseball that was moving toward her. She hit the baseball and it traveled in the opposite direction, right out of the park!

2. Work with a partner and use the words on the cards to create sentences that describe what actually happened to the baseball when Mary hit it with the bat. Do this aloud or use scratch paper.
3. Use at least two words from the word bank in each sentence. You don't have to use all the words.
4. Create as many sentences as you can. You are not limited to a one-sentence description. In fact, try to use more than one sentence to express your ideas.
5. When you are finished creating sentences, join another pair and share your sentences.

Word Bank

cause	effect	force	velocity

Name: _____ Date: _____

Investigating Strong and Weak Forces

Use the launcher to exert different strength forces on the jar lids. Observe how the velocity changes in response to different strength forces. Review the steps below.

What will you change (the independent variable) in each test?_____

What will you observe (the dependent variable) as a result of that change? _____

_____

What will be kept the same (control) in each test?_____

1. Lay a meter stick on the floor or table.
2. Place two jar lids on the floor or table, one on each side of the meter stick at the end, or at 0 cm.
3. Exert a different force on each jar lid, but release the launchers at the same time.
   - Have one partner press the launcher to the ***2*** mark (force 2).
   - Have the other partner press the launcher to the ***3*** mark (force 3).
4. Observe which jar lid is the first to reach the opposite end of the meter stick.
5. Record your observations in the data table.
6. Repeat this process twice so you have data for three trials, and then answer the questions.

Trial number	Which jar lid reached the end of the meter stick first? (force 2 or 3)
Trial 1	
Trial 2	
Trial 3	

Wait to answer these questions until you have completed all three trials.

1. Which mark exerted the stronger force? (check one)

   ☐ mark 2 (force 2) ☐ mark 3 (force 3) ☐ both exerted the same strength force

2. Which force caused the jar lid to travel faster and reach the end of the meter stick first? (check one)

   ☐ the weaker force ☐ the stronger force ☐ both forces had the same effect

3. Circle the bold phrase that completes the sentence to match your observations:

   When you exert a stronger force on an object, you will see (**a greater** | **a smaller** | **the same**) change in velocity as compared to exerting a weaker force on the same object.

Name: _____ Date: _____

Homework: Reading "Friction"

1. Review the focus questions before you read the article.
2. Keep the questions in mind while you read, and highlight or annotate any information that might help you answer those questions.
3. After you are finished reading, answer the questions.

Focus Questions

1. Why does an object that is sliding across carpet slow down?

_____

_____

_____

_____

2. Compare an object sliding across carpet and that same object sliding across a bare floor. Why is the object quicker to slow down on carpet than on the bare floor?

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 1.5: Force Strength and Velocity Change

Today, you will build on your understanding of how forces cause different velocity changes. You will further investigate how an object can experience a greater change in velocity by completing a set of missions in the *Force and Motion* Sim. After that, you will apply what you know about force and changes in velocity by creating visual models.

Unit Question

- How do forces affect motion?

Chapter 1 Question

- What caused the pod to change direction?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.

Vocabulary

- cause
- effect
- exert
- force
- friction
- infer
- velocity

Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Modeling Tool activity: Different Velocity Changes

Name: _____ Date: _____

Warm-Up

1. Review the definition of friction.
2. Consider the two events and answer the questions.

friction: a force between an object and the surface it is moving over

Imagine you push a book across an incredibly slippery surface. It slides right across because there is no friction. Next, you push the same book across a rougher surface that exerts friction.

Will the velocity of the book change as it moves across the surface with no friction? Explain your answer.

_____

_____

_____

_____

Will the velocity of the book change as it moves across the surface with friction? Explain your answer.

_____

_____

_____

_____

Name: _____ Date: _____

Force Strength and Velocity Change

Work with a partner to conduct a series of Sim missions that will make objects reach their targets at the specified velocity. Your challenge is to complete each mission by exerting a force on the object **only once**. That force can be of any strength or direction.

1. Open the *Force and Motion* Simulation.
2. Select the first mission, 1.5 Mission 1, from the menu bar and read the mission task.
3. Note the object's initial velocity in the data table and discuss with your partner how you might achieve the goal.
4. Press RUN and then press PREPARE FORCE to pause the Sim while you set up your force.
5. Use the arrows in the force panel to set up a single force for the object that will cause the correct velocity change.
6. Press EXERT FORCE and observe the results. If the mission is a success, the object will disappear.
7. When you succeed at a mission, press ANALYZE. Record the strength of the force and the object's change in velocity in the data table.
8. Repeat steps 2–7 for each mission.
9. Answer the question on the next page.

Tips

- You do not have to prepare your forces immediately. Sometimes it is better to wait until the right moment!
- Compare the object's initial velocity to the velocity shown on the target. This will give you a hint about how strong your force should be.

Mission	**Object's initial velocity**	**Change in velocity** (speed up, slow down, start, stop, change direction)	**Force direction**	**Force strength**	**Change in velocity** (cm/s)
1	0 cm/s				
2	2 cm/s right				
3	5 cm/s left				
4	5 cm/s right				
5	3 cm/s left				

Name: _____ Date: _____

Force Strength and Velocity Change (continued)

What do you notice about the relationship between the force strength and the size of the velocity change?

_____

_____

_____

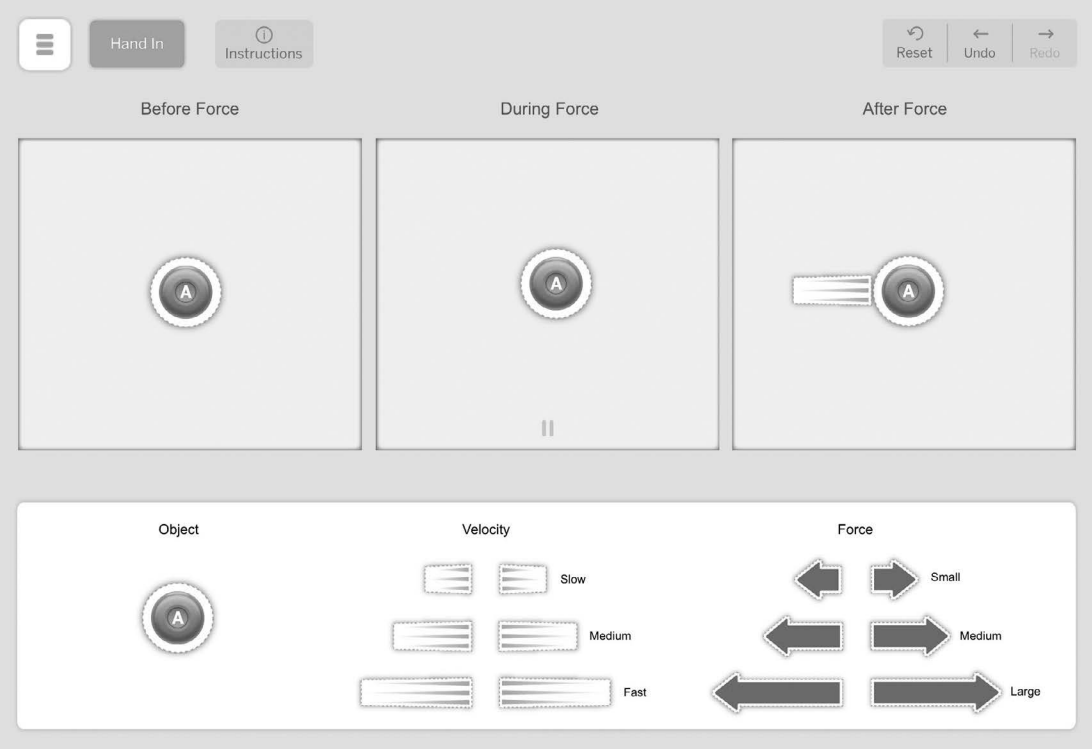
_____

If you have time, complete the optional missions 6, 7, and 8, and record your results.

Mission	**Object's initial velocity**	**Change in velocity** (speed up, slow down, start, stop, change direction)	**Force direction**	**Force strength**	**Change in velocity** (cm/s)
6	0 cm/s				
7	6 cm/s right				
8	4 cm/s right				

Name: _____ Date: _____

Modeling Force and Velocity



1. Open the *Force and Motion* Modeling Tool activity: Different Velocity Changes.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Model the force that would cause each velocity change.

Do:

- Drag one force arrow into each During Force panel so it shows the direction and strength of the force exerted on each object.

Name: _____ Date: _____

Lesson 1.6: Evaluating Claims and Thruster Forces

Dr. Gonzales has asked for your help in determining whether a problem with the pod's thrusters (the strength of force exerted) could have caused it to reverse direction and move away from the space station. You will return to the two claims about what could have happened during the time the space agency lost communication. You will need to decide whether a problem with the thrusters is the best explanation for what happened.

Unit Question

- How do forces affect motion?

Chapter 1 Question

- What caused the pod to change direction?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.
- A stronger force can cause a greater change in velocity.

Vocabulary

- cause
- effect
- exert
- force
- infer
- velocity

Digital Tools

- *Force and Motion* Modeling Tool activity: Claim 1 and Claim 2

Name: _____ Date: _____

Warm-Up

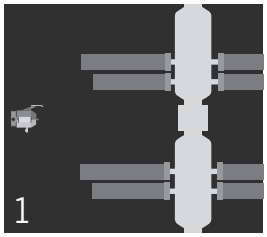
ACM pods normally fire the thrusters with a force that stops the pod and allows it to dock at the space station. For this pod, something else happened.

Think about the thruster force in successful missions, and then compare that to the thruster force that would cause the situation in each of the claims.

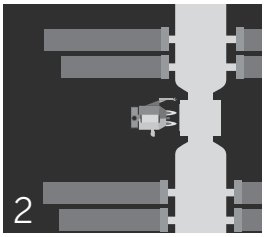
Normally, when the thrusters fire, the pod will stop, but this mission was different.

Claim 1: The thrusters caused the pod to move in the opposite direction.

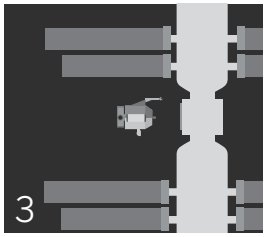
Claim 2: The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction.



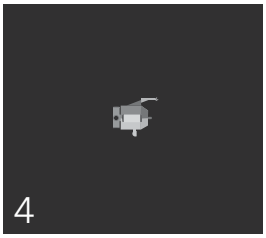
Pod approaches space station at medium speed.



Thrusters fire to stop the pod.



Thrusters cause pod to move in opposite direction OR pod hits space station and bounces off.



Pod travels far away from the space station.

Circle the bold phrase that completes each claim.

Claim 1: If this pod went in the opposite direction because of the thrusters, the thrusters would have exerted (**a force stronger than** | **a force weaker than** | **an equal force to**) the thrusters in other missions.

Claim 2: If this pod crashed into the space station because of the thrusters, the thrusters would have exerted (**a force stronger than** | **a force weaker than** | **an equal force to**) the thrusters in other missions.

Name: _____ Date: _____

Modeling Thruster Forces

Ana Gonzales
To: Student Physicists
Re: Thruster Problem

UNIVERSAL SPACE AGENCY

Great work so far on your investigation into what happened when we lost contact with the ACM pod. As our team investigates what kept this pod from docking, your models and arguments will play a key role in helping us understand what could have caused the pod to move away from the space station. Was there a problem with the strength of force exerted by the thrusters? Your explanations will help us interpret the data we are trying to recover from the pod. We hope to have some data soon.

Keep up the thorough work!

Dr. Ana Gonzales, Program Scientist
Asteroid Collection Mission

Name: _____ Date: _____

Modeling Thruster Forces (continued)

Modeling Claim 1

1. Open the *Force and Motion* Modeling Tool activity: Claim 1, Chapter 1.

2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Model the force that would cause the pod to move in the opposite direction.

Do:

- Use the first row as a reference; use the second row to show what happened to this pod.
- Drag one force arrow into the During Force panel so it shows the direction and strength of the thruster force.
- Drag velocity lines into the After Force panel so it shows the pod's final velocity.

Modeling Claim 2

1. Open the *Force and Motion* Modeling Tool activity: Claim 2, Chapter 1.

2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Model the force that would only slow the pod (not stop it) and cause it to hit the space station.

Do:

- Use the first row as a reference; use the second row to show what happened to this pod.
- Drag one force arrow into the During Force panel so it shows the direction and strength of the thruster force.
- Drag velocity lines into the After Force panel so it shows the pod's final velocity.

Name: _____ Date: _____

Explaining Thruster Forces

1. Explain the events that would cause these changes in velocity. For each claim, describe the thruster force and how that would result in the pod moving away from the station.
   - **Claim 1:** The thrusters caused the pod to move in the opposite direction.
   - **Claim 2:** The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction
2. Use the word bank, cause-and-effect words and phrases, and your two Modeling Tool diagrams, if they are helpful.

Word Bank

force	exert	velocity	cause	effect

Cause-and-Effect Words and Phrases

if . . . , then	because	as a result	this led to . . .
when	therefore	next	

Claim 1: Firing the thrusters would have caused the pod to move in the opposite direction if . . .

_____

_____

_____

_____

_____

Claim 2: Firing the thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction. This would happen if . . .

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the ACM pod during the time when Mission Control lost contact?

1. I understand how forces could have caused the pod to move in the opposite direction. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

2. I understand how something about the pod could have affected its velocity change. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

3. I understand the forces in a collision, which is the moment when two objects hit each other. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

4. I understand why the objects in a collision can have different changes in motion. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

5. What do you still wonder about force and motion as they relate to the Asteroid Collection Mission that did not go as planned?

   _____

   _____

Name: _____ Date: _____

Chapter 2: Mass and Velocity
Chapter Overview

The Universal Space Agency sent a message saying that the pod's thrusters exerted the same strength force they always do. How could the same thruster force have caused a difference in velocity for the pod? You will continue your investigation by exploring the relationship between force, mass, and velocity, looking for evidence about how equal forces affect the velocity of objects of different mass.

Name: _____ Date: _____

Lesson 2.1: Exploring Mass, Force, and Velocity

Student physicists, the space agency has found that this pod's thrusters exerted the same strength force as pods on other missions, but this time the force exerted did not cause the pod to stop. How could the same force cause a different velocity change? Was something different about this pod? How can we explain this surprising result? Let's go find out!

Unit Question

- How do forces affect motion?

Chapter 2 Question

- The thrusters on the ACM pod exerted the same strength force as thrusters on other pods, so why did this pod move differently?

Vocabulary

- cause
- effect
- exert
- force
- infer
- velocity

Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Data Tool activity: Proportional Relationships

Name: _____ Date: _____

Warm-Up

Ana Gonzales
To: Student Physicists
Re: Thruster Problem

UNIVERSAL SPACE AGENCY

Thank you for sharing your models and explanations. This information is very helpful!

We analyzed the thruster data from the pod and found that the thrusters exerted the ***same strength force*** as in other missions. Since this pod didn't stop, we'll need to look at another cause.

The pod had been collecting asteroid samples, and we aren't sure how many it was carrying. Could a difference in the number of asteroid samples explain why the same thruster force caused a different change in velocity? We'd really appreciate your help with this.

Dr. Ana Gonzales, Program Scientist
Asteroid Collection Mission

Do you think the number of asteroid samples a pod is carrying could make a difference? Might that explain why the same strength thruster force caused this pod to have a different change in velocity? Explain your ideas, even if you are unsure.

Name: _____ Date: _____

Investigating Forces on Different Objects

Part 1:

If the same strength force is exerted on two objects, why might they be affected differently?

1. Think about what you already know. Why might two objects be affected differently if the same strength force is exerted on them?

_____

_____

_____

Plan an investigation to test your ideas.

2. What will you change (the independent variable) in each test? _____

3. What will you observe (the dependent variable) as a result of that change? _____

_____

4. What tools do you need to measure results? _____

5. What will you keep the same (control) in every test?

_____

_____

6. How many trials should you conduct for each object? Why?

_____

_____

_____

Part 2:

Pick up the golf ball and the table tennis ball. Compare the two objects and record your observations.

Lighter object: (circle one) **golf ball** **table tennis ball**

Heavier object: (circle one) **golf ball** **table tennis ball**

Name: _____ Date: _____

Investigating Forces on Different Objects (continued)

Part 2 continued:

1. Work with a partner and use your responses on page 34 to decide how you will carry out your investigation. Describe your steps in the space provided.
2. Create a data table to record the results of your tests.
3. Conduct your investigation and record your results. Then, answer the questions below.

Steps:

Data Table:

4. Analyze your data. What do you notice?

_____

_____

_____

5. Why might two objects be affected differently if the same strength force is exerted on them?

_____

_____

_____

Name: _____ Date: _____

Investigating Force and Mass

Force and Mass: Objects That Are Not Moving (Motionless)

Use the Sim to investigate how the same strength force affects objects of different mass when those objects are not moving.

1. Open the *Force and Motion* Simulation.
2. From the menu, select **2.1 Motionless Objects**.
3. Press RUN, then press PLAY to begin.
4. Observe the initial velocity of the objects, then press PREPARE FORCE to pause the Sim while you set up the forces described in your data table.
5. Use the arrows in the Force panel in the bottom right corner of the screen to set up a force on Object A.
6. Select Object B in the Force panel and use the arrows to set up a force on Object B. Repeat for Object C and Object D.
7. Press EXERT FORCE to exert the forces and observe how each object's velocity changes.
8. Press ANALYZE. Record each object's change in velocity.
9. Respond to the question.

Object	Mass (kg)	Initial velocity (cm/s)	Prepared force	Change in velocity (cm/s)
A	0.5	0	4 clicks to right	
B	1	0	4 clicks to right	
C	2	0	4 clicks to right	
D	4	0	4 clicks to right	

Which object's velocity changed the most? (circle one)

Object A **Object B** **Object C** **Object D**

Name: _____ Date: _____

Investigating Force and Mass (continued)

Force and Mass: Moving Objects

Use the Sim to investigate how the same strength force affects objects of different mass when those objects are already moving.

1. Open the *Force and Motion* Simulation.
2. From the menu, select **2.1 Moving Objects**.
3. Press RUN, then press PLAY to begin.
4. Observe the initial velocity of the objects, then press PREPARE FORCE to pause the Sim while you set up the forces described in your data table.
5. Use the arrows in the Force panel in the bottom right corner of the screen to set up a force on Object A.
6. Select Object B in the Force panel and use the arrows to set up a force on Object B. Repeat for Object C and Object D.
7. Press EXERT FORCE to exert the forces and observe how each object's velocity changes.
8. Press ANALYZE. Record each object's change in velocity.
9. Respond to the question.
10. If you have time, give the challenge task (2.1 Challenge Mission) a try.

Object	Mass (kg)	Initial velocity (cm/s)	Prepared force	Change in velocity (cm/s)
A	0.5	2 cm/s left	4 clicks to right	
B	1	2 cm/s left	4 clicks to right	
C	2	2 cm/s left	4 clicks to right	
D	4	2 cm/s left	4 clicks to right	

Which object's velocity changed the most? (circle one)

Object A **Object B** **Object C** **Object D**

Name: _____ Date: _____

Lesson 2.2: "Designing Wheelchairs"

What else could have caused this pod to move differently? Knowing that the thrusters exerted the same strength force as the thrusters on other ACM pods does not explain why it failed to dock. In today's lesson, you will learn more about another factor, mass, and how that could have affected the pod's change in velocity. Your research will continue with an article called "Designing Wheelchairs for All Shapes and Sizes." Remember, the Universal Space Agency is counting on your help!

Unit Question

- How do forces affect motion?

Chapter 2 Question

- The thrusters on the ACM pod exerted the same strength force as thrusters on other pods, so why did this pod move differently?

Vocabulary

- cause
- effect
- exert
- force
- infer
- velocity

Name: _____ Date: _____

Warm-Up

You have investigated many questions about forces and how different objects move using the Sim and other common materials (jar lids, table tennis balls, etc.). What are some questions you still have about forces, the movement of objects, speed, or velocity? What materials or tools would you use to investigate your questions?

List questions that you have:

_____

_____

_____

_____

Explain what materials you would use to investigate your questions:

_____

_____

_____

_____

After thinking of questions and materials, scientists often make predictions, or hypotheses, about what they might find in an investigation. Choose one of your questions from above and write a prediction, or hypothesis, about what you might find in your investigation.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Designing Wheelchairs"

1. Read and annotate the article "Designing Wheelchairs."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 2.3: Explaining Mass, Force, and Velocity

Through your investigations, you've learned that mass plays an important role in determining how much an object's velocity changes when a force is exerted on that object. It's time to apply what you know about the relationship between mass, force, and velocity change to the case of the pod that failed to dock. You will conduct tests in the Sim and reread a text, then create two models. These models will show how the pod's mass could have been a key factor in either explanation of the docking failure.

Unit Question

- How do forces affect motion?

Chapter 2 Question

- The thrusters on the ACM pod exerted the same strength force as thrusters on other pods, so why did this pod move differently?

Vocabulary

- cause
- effect
- exert
- force
- infer
- velocity

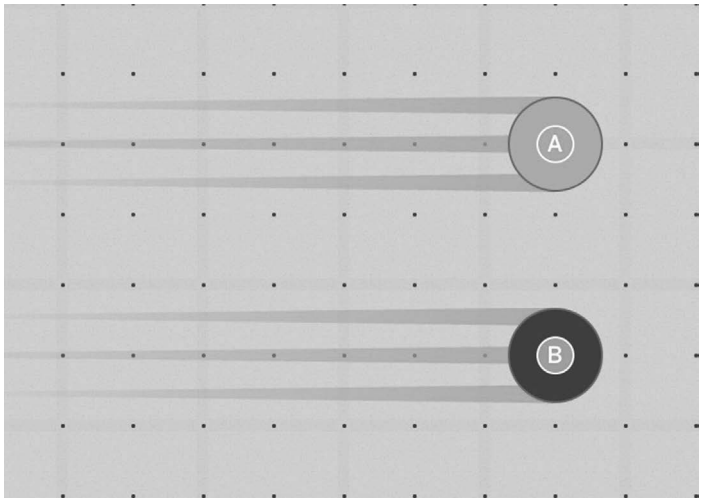
Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Modeling Tool activities: Claim 1, Chapter 2 and Claim 2, Chapter 2

Name: _____ Date: _____

Warm-Up

1. Make some predictions about what will happen in the Sim when you exert the same strength force on two objects of different mass.
2. Run the tests in the Sim.
3. When the tests are complete, think about how you would answer this question: *Why did one object stop more easily than the other?* Be prepared to share your ideas with a partner.



Predictions

1. If your goal is to make these objects slow down, in which direction should you apply a force? (circle one)

   up **down** **left** **right**

2. Object B is more massive than Object A. If you apply the same strength force (4 clicks) to both objects, which object will have a greater change in velocity? (circle one)

   Object A **Object B**

Sim Tests

1. Open the *Force and Motion* Simulation and select **2.3 Warm-Up** from the menu.
2. Press RUN, then press PLAY to begin.
3. Press PREPARE FORCE to pause the Sim while you set up your forces.
4. In the Force panel, select Object A and set up a force of 4 clicks in the direction that will make the object slow down.
5. Repeat step 4 for Object B.
6. Press EXERT FORCE and observe how each object's velocity changes.

Name: _____ Date: _____

Revisiting "Designing Wheelchairs"

How would you design a wheelchair for basketball? The players need the wheelchair to be stable, or at least not tip over when there's contact between players. Players also need to be able to stop and start quickly and move fast so they can gain control of the basketball.

1. Reread paragraphs 3, 4, and 5 of "Designing Wheelchairs for All Shapes and Sizes." Highlight or annotate evidence in the text that helps you understand how massive a wheelchair for basketball needs to be.
2. Discuss your ideas with a partner after you finish reading.
3. Answer the questions and record your design ideas, including ideas from the text that support your design choice.
4. Be prepared to share your ideas with the class.

Questions

Which wheelchair would be more difficult to stop? (check one)

- ☐ more massive wheelchair
- ☐ less massive wheelchair

If the same strength force were exerted on both wheelchairs, which chair would go faster? (check one)

- ☐ more massive wheelchair
- ☐ less massive wheelchair

How would you design a wheelchair for wheelchair-using basketball players? Would you make it more or less massive? Explain how the text supports your choice.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Modeling the Effects of Different Masses

Claim 1

1. Open the *Force and Motion* Modeling Tool activity: Claim 1, Chapter 2.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: _____

Goal: Model this pod's mass so it shows that the usual thruster force would cause it to move in the opposite direction.

Do:

- Choose an object that represents the mass of this pod. Drag it into all three panels in the second row.
- Show the pod's velocity in the Before and After Force panels.
- Show the direction and strength of the thruster force in the During Force panel.

Tips:

- The During Force panel for this pod should use the same strength and direction of force as the pod in the first row.

Name: _____ Date: _____

Modeling the Effects of Different Masses (continued)

Claim 2

1. Open the *Force and Motion* Modeling Tool activity: Claim 2, Chapter 2.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: _____

Goal: Model this pod's mass so it shows that the usual thruster force would only slow the pod (not stop) and cause it to hit the space station.

Do:

- Choose an object that represents the mass of this pod. Drag it into all three panels in the second row.
- Show the pod's velocity in the Before and After Force panels.
- Show the direction and strength of the thruster force in the During Force panel.

Tips:

- The During Force panel for this pod should use the same strength and direction of force as the pod in the first row.

Name: _____ Date: _____

Homework: Explaining Two Claims

Why did this pod move differently? Could these claims be accurate if the pod had a different mass (a different number of asteroid samples)? Explain to Dr. Gonzales what would have happened in each claim that would cause the pod to move away from the space station.

Refer to your Modeling Tool diagrams, the word bank, and the cause-and-effect words and phrases.

Word Bank

force	exert	mass	velocity	cause	effect

Cause-and-Effect Words and Phrases

if . . . , then	because	as a result	this led to . . .
when	therefore	next	

Claim 1: Firing the thrusters would have caused the pod to move in the opposite direction if . . .

_____

_____

_____

_____

_____

_____

Claim 2: Firing the thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction. This would happen if . . .

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.5: Reviewing Mass, Force, and Velocity

In this lesson, you will use the Sim to review key concepts that describe the relationship between force, mass, and change in velocity. You will then review some new data about the pod to help you figure out which of the two claims is more accurate. This new information could put you one step closer to solving the mystery caused by those seconds when we lost communication.

Unit Question

- How do forces affect motion?

Chapter 2 Question

- The thrusters on the ACM pod exerted the same strength force as thrusters on other pods, so why did this pod move differently?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.
- A stronger force can cause a greater change in velocity.
- Understanding a cause-and-effect relationship can help you infer what led to a particular result.
- If the same strength force is exerted on two objects but the objects have different masses, the object with less mass will have a greater change in velocity.

Vocabulary

- cause
- effect
- exert
- force
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Sorting Tool activity: Force and Velocity

Name: _____ Date: _____

Warm-Up

1. Open the *Force and Motion* Sorting Tool activity: Force and Velocity.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: _____

Goal: Match the key concept to the pair of diagrams that illustrate its cause-and-effect relationship.

Do:

- Determine what each pair of diagrams is saying by comparing the top and bottom images in each column.
- Drag a key concept card to the appropriate column.

Tips:

- Read each diagram from left to right.
- Each diagram shows the object at all three times: before the force is exerted, during the force, and after the force is exerted.

Name: _____ Date: _____

Purple Group: Reviewing Force and Velocity

Part 1: Explore

1. Select **2.5 Purple Explore** from the *Force and Motion* Sim menu.
2. Tap on Object A and record its initial velocity:

   direction: _____ speed: _____ cm/s

3. Press RUN and then press PREPARE FORCE.
4. Set up and test the force that will cause each desired velocity change (a–d) listed in the data table below. Each velocity change can use **only one force**.
   - Use the Force panel to set up the force direction and force strength.
   - Press EXERT FORCE.
   - Observe the object's motion. Did you cause the desired change? (**Hint:** Press ANALYZE for data about velocity. Use the slider to view data about force strength.)
   - If yes, record the Force Direction and Force Strength and go on to the next desired change.
   - If no, press RESET and try again with a different direction or strength.

Desired velocity change	Force direction	Force strength
a. speed up to 7 cm/s right		
b. speed up to 10 cm/s right		
c. slow down to 0 cm/s right (stop)		
d. reverse direction to 2 cm/s left		

5. When you have finished Part 1, move on to Part 2.

Name: _____ Date: _____

Purple Group: Reviewing Force and Velocity (continued)

Part 2: Predict

1. If you exert the same strength force on two objects, one with a greater mass and the other with less mass, which object will reach the target first? (check one)

   ☐ a. the object with a greater mass

   ☐ b. the object with less mass

   ☐ c. both objects at the same time

2. What should you do to make sure that both objects reach the target at the same time?

   _____

Part 2: Test

3. Complete three missions: **2.5 Purple Mission 1**, **2.5 Purple Mission 2**, and **2.5 Purple Mission 3**.
4. Select a mission and read the prompt.
5. Press RUN and then press PREPARE FORCE.
6. Set up the forces and test your results.
   - Use the Force panel to set the force direction and force strength for each object (A and B).
   - Press EXERT FORCE.
   - Observe the objects. Did they reach the targets at the same time? (**Hint:** Press ANALYZE and use the slider to view data about force strength.)
   - If yes, record the Force Direction and Force Strength and move on to the next mission.
   - If no, press RESET and try again with a different direction or strength.

Mission title	**Object A: Force direction/strength**	**Object B: Force direction/strength**
2.5 Purple Mission 1		
2.5 Purple Mission 2		
2.5 Purple Mission 3		

7. After you finish, answer the reflection questions on the next page.

Name: _____ Date: _____

Purple Group: Reflecting on Force and Velocity

1. An object is moving to the left.

   a. In which direction would a force need to be exerted to make this object **speed up**? (circle one)

   left **right** **up** **down**

   b. In which direction would a force need to be exerted to make this object **slow down**? (circle one)

   left **right** **up** **down**

   c. In which direction would a force need to be exerted to make this object **stop**? (circle one)

   left **right** **up** **down**

Object A:
Mass 1

Object B:
Mass 4

The same strength force is exerted in the same direction on objects of different mass.

2. The same strength force was exerted in the same direction on both Object A and Object B. Why did Object A go faster than Object B?

_____

_____

_____

Name: _____ Date: _____

Blue Group: Reviewing Force and Velocity

Part 1: Test

1. Select **2.5 Blue Mission 1** from the *Force and Motion* Sim menu and read the mission prompt.
2. Press RUN and record the mass of each object:

   Object A: _____ kg Object B: _____ kg Object C: _____ kg
3. Press PREPARE FORCE.
4. Set up the forces and test your results.
   - Use the Force panel to set the force strength and direction for each object (A, B, and C).
   - Press EXERT FORCE.
   - Observe the objects. Did they reach the targets at the requested velocity? (**Hint:** Press ANALYZE for data about velocity. Use the slider to view data about force strength.)
   - If yes, record the Force Strength/Direction and go on to the next mission.
   - If no, press RESET and try again with a different direction or strength of force.

Mission	**Object A: Force strength/ direction**	**Object B: Force strength/ direction**	**Object C: Force strength/ direction**
2.5 Blue Mission 1			
2.5 Blue Mission 2			
2.5 Blue Mission 3			

5. After you complete Part 1, go on to Part 2.

Name: _____ Date: _____

Blue Group: Reviewing Force and Velocity (continued)

Part 2: Predict

1. If you exert the same strength force on two objects, one with a greater mass and the other with less mass, which object will reach the target first? (check one)

   ☐ a. the object with a greater mass

   ☐ b. the object with less mass

   ☐ c. both objects at the same time

2. What should you do to make sure that both objects reach the target at the same time?

   _____

Part 2: Test

1. Complete three missions: **2.5 Blue Mission 4**, **2.5 Blue Mission 5**, and **2.5 Blue Mission 6**.
2. Select a mission and read the prompt.
3. Press RUN and then press PREPARE FORCE.
4. Set up the forces and test your results.
   - Use the Force panel to set the force direction and force strength for each object (A and B).
   - Press EXERT FORCE.
   - Observe the objects. Did they reach the targets at the same time?
   - Press ANALYZE and use the slider for data about force strength.
   - Record the Force Strength/Direction and go to the next mission if you were successful.
   - If not, press RESET and try again with a different direction or strength.

Mission title	**Object A: Force strength/direction**	**Object B: Force strength/direction**
2.5 Blue Mission 4		
2.5 Blue Mission 5		
2.5 Blue Mission 6		

5. After you finish, answer the reflection questions on the next page.

Name: _____ Date: _____

Blue Group: Reflecting on Force and Velocity

Object A: Mass 1	Object B: Mass 4	Object C: Mass 0.5

You exert a force on Object A (see image above) and it speeds up.

1. Object B has more mass than Object A. How would the velocity of Object B change if you exerted the same strength force on Object B as you did on Object A? Why?

_____

_____

_____

_____

2. Object C is half the mass of Object A. What strength force would you need to exert on Object C to make it have the same velocity change as Object A? Why?

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Reviewing Force and Velocity

Part 1: Predict

An object is moving diagonally (down and to the left). You want it to stop moving. In what direction (or directions) should you exert a force to get the object to stop?

a. Force direction(s): _____ _____ _____

b. Explain your answer: _____

Part 1: Test

1. There are four missions in this part and each mission has two tasks. Select the **2.5 Green Mission 1** from the *Force and Motion* Sim menu and read the mission prompt that describes both tasks.
   - **Task 1** asks you to use **multiple forces** to achieve a goal.
   - **Task 2** asks you to achieve the same goal, but using **a single force**.
2. Press RUN and attempt Task 1.
   - Observe the object. Did it reach the target?
   - If yes, press RESET and go on to Task 2.
   - If not, press RESET and try again with forces of different strengths and directions.
3. For Task 2, press RUN and PREPARE FORCE.
4. Set up the single force and test your results.
   - Use the Force panel to set the force directions and strengths.
   - Press EXERT FORCE.
   - Observe the object. Did it reach the target?
   - If yes, go on to the next mission. After completing Mission 4, respond to **Part 1: Apply**.
   - If no, press RESET and try again using different force strengths and directions.

Part 1: Apply

1. An object is moving to the right. Instead, you want it to move up (but not in a diagonal). In what direction (or directions) should you exert a force to get the object to move upward?

a. Force direction(s): _____ _____ _____

b. Explain your answer: _____

2. Go on to Part 2.

Name: _____ Date: _____

Green Group: Reviewing Force and Velocity (continued)

Part 2: Test

1. Complete four more missions: **2.5 Green Mission 5**, **2.5 Green Mission 6**, **2.5 Green Mission 7**, and **2.5 Green Mission 8**.
2. Select **Mission 5** and read the prompt.
3. Press RUN.
   - Use the Force panel to get the object moving. Did it reach the target without touching the walls?
   - If yes, go on to the next mission.
   - If not, press RESET and try again with forces of different strengths and directions.
4. After Mission 8, respond to **Part 2: Explain.**

Part 2: Explain

Two objects are moving downward at a speed of 3 cm/s. Object A has a mass of 2 kg and Object B has a mass of 1 kg. You want both objects to move to the left at a speed of 3 cm/s.

(**Hint:** If you get stuck or want to check your ideas, test them in the Sim.)

1. In what direction (or directions) should you exert the forces that will make the desired change?

   force direction(s): _____ _____ _____

2. Describe what strength force or forces would be needed to cause the desired velocity change: Make Object A and Object B move to the left at 3 cm/s.

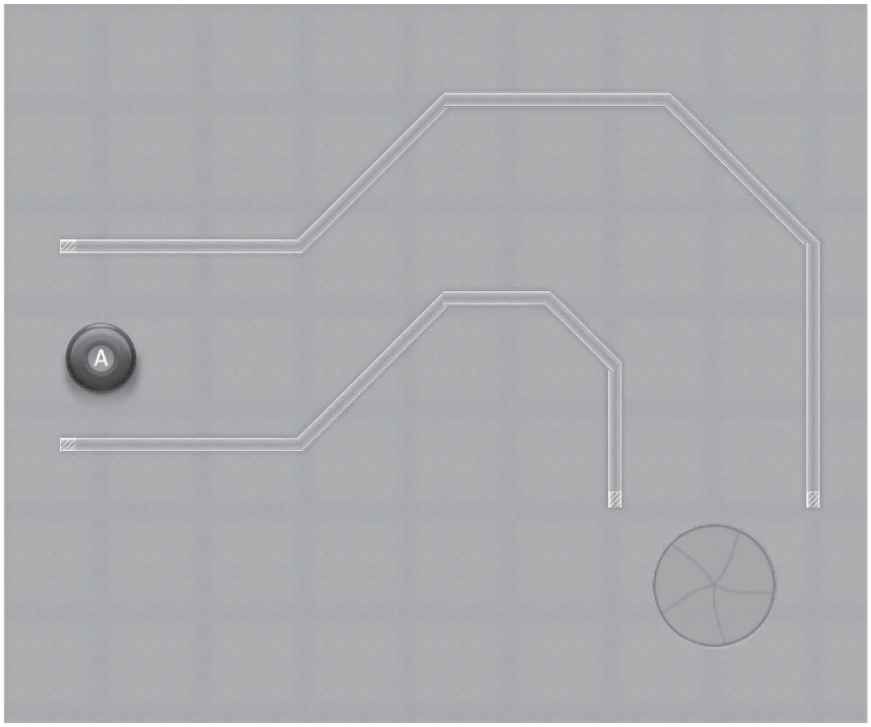
_____

_____

3. When you have finished Part 2, move on to the reflection question on the next page.

Name: _____ Date: _____

Green Group: Reflecting on Force and Velocity



Describe the direction of the forces you would exert in the Sim to make the object reach the target without touching any of the walls. Use only UP, DOWN, LEFT, and RIGHT. Explain your reasoning. When would you exert these forces? Why?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Explaining Forces and Velocity Change

Ana Gonzales
To: Student Physicists
Re: !! Asteroid Samples and the Pod

UNIVERSAL SPACE AGENCY

We've just been able to recover some useful data from the pod!

The mass of the pod is 1,100 kg, and that is 130 kg more than usual. This means the pod was carrying more asteroid samples than the pods normally carry, so it is more massive.

We hope this data will help you explain what happened to the pod during the short time when we lost contact.

Dr. Ana Gonzales, Program Scientist
Asteroid Collection Mission

Which claim do you think is best supported by this new evidence? Discuss the data and claims with your partner and if helpful, use the words in the word bank.

- **Claim 1:** The thrusters caused the pod to move in the opposite direction.
- **Claim 2:** The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction.

Word Bank

cause	effect	exert	force	mass	velocity

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the ACM pod during the time when Mission Control lost contact?

1. I understand how forces could have caused the pod to move in the opposite direction. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

2. I understand how something about the pod could have affected its velocity change. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

3. I understand the forces in a collision, which is the moment when two objects hit each other. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

4. I understand why the objects in a collision can have different changes in motion. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

5. What do you still wonder about force and motion as they relate to the Asteroid Collection Mission that did not go as planned?

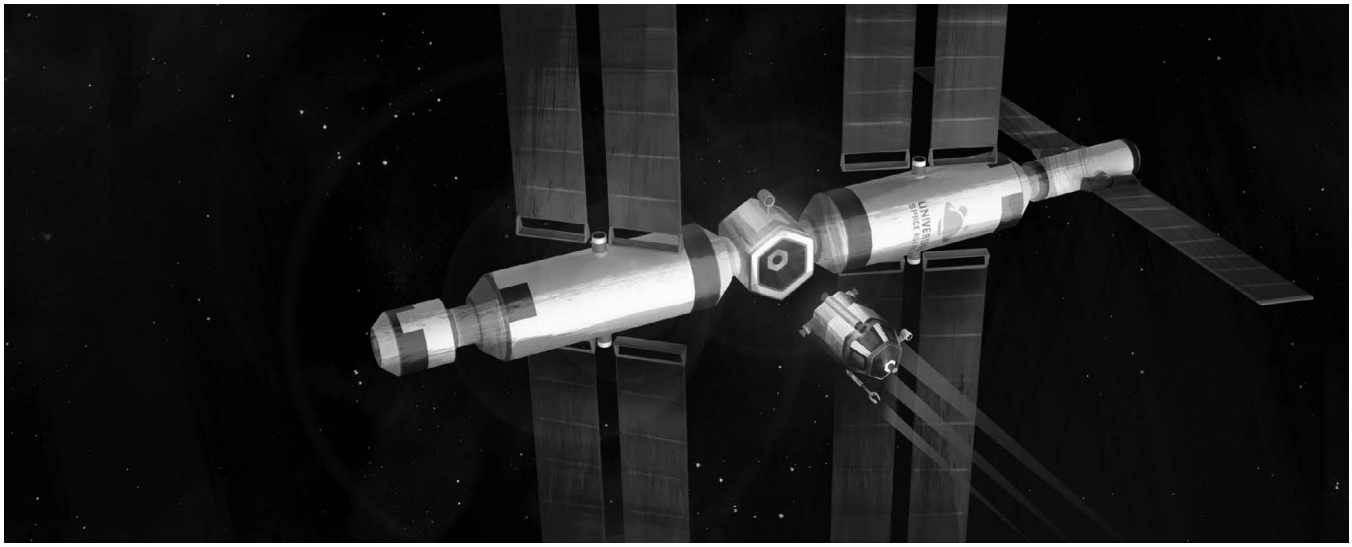
   _____

   _____

Name: _____ Date: _____

Chapter 3: Collisions
Chapter Overview

The Universal Space Agency learned that it's not just the pod that's moving—the space station is also moving! They want to retrieve the pod, but they need to figure out how fast the pod is moving compared to the space station. Is the pod moving slowly enough that it can be retrieved? You will finish your investigation for the USA by exploring what forces are like in collisions and how these forces affect the motion of each object.



Name: _____ Date: _____

Lesson 3.1: "Crash!"

Dr. Ana Gonzales's team urgently needs to find out whether the pod and its asteroid samples are still close enough to the space station to be retrieved. They want to know how fast the pod has been moving since it hit the space station. Today, you'll begin to investigate what forces are like when objects collide, and this will help you determine what happened when the pod collided with the space station.

Unit Question

- How do forces affect motion?

Chapter 3 Question

- After the collision, how does the pod's motion compare to the motion of the space station?

Vocabulary

- cause
- collision
- effect
- exert
- force
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Simulation

Name: _____ Date: _____

Warm-Up

Ana Gonzales
To: Student Physicists
Re: Possible Pod Rescue

UNIVERSAL SPACE AGENCY

So, thanks to you, we understand that even though the thruster force is the same strength on all pods, this pod was affected differently because it is more massive. The thrusters could only slow this pod, and since it didn't stop, it hit the space station.

Our team is thinking about a rescue mission, but we also learned that the crash made the space station move! We know the collision caused the pod to move in the opposite direction, but is the pod faster, the same speed, or slower than the space station? How far away from the space station is the pod? How fast is the pod moving? Is a rescue mission possible? Once again, we need your help with our questions!

Dr. Ana Gonzales, Program Scientist
Asteroid Collection Mission

Record your initial ideas by answering these questions:

If two objects crash into each other, what happens? Are both objects affected? How? If you can, give an example to support your ideas.

Name: _____ Date: _____

Reading "Crash!"

1. Read and annotate the article "Crash!"
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost Never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Exploring Collision Forces

What are the forces like in a collision?

1. Open the *Force and Motion* Simulation.
2. Select **3.1 Homework** from the menu.
3. Set up collisions between objects and observe the forces and changes in velocity.
   Things you may want to try:
   - A collision where an object runs into another object that is not moving.
   - A collision where an object runs into another object that is moving in the opposite direction.
   - A collision where an object runs into another object that is moving in the same direction.
   - A collision between two objects that have the same mass.
   - A collision between two objects that have different masses.

What do your observations show you about the forces exerted on objects in a collision?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 3.2: Investigating Collision Forces

When objects collide, their motion doesn't seem to change the same way. Does this happen because the forces that move the objects are different? In this lesson, you will discover the characteristics of forces in a collision and determine the direction in which these forces are exerted. You will also use the Sim to determine how strong these forces are. What are the forces like in a collision? Let's find out!

Unit Question

- How do forces affect motion?

Chapter 3 Question

- After the collision, how does the pod's motion compare to the motion of the space station?

Vocabulary

- cause
- collision
- effect
- exert
- force
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Simulation
- *Force and Motion* Modeling Tool activity: Collision Forces

Name: _____ Date: _____

Warm-Up

1. Open the *Force and Motion* Modeling Tool activity: Collision Forces.
2. Use the Modeling Tool to show your initial ideas.
3. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here:

   _____

Goal: Match the forces exerted when two objects collide (strength and direction).

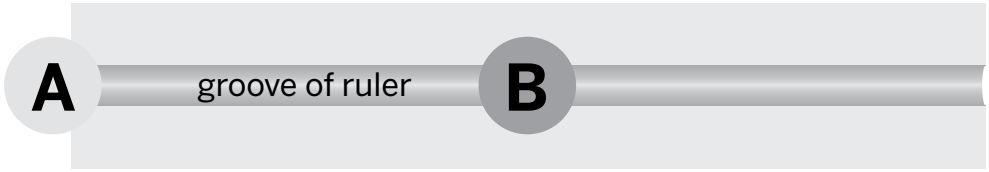
Do: Drag force arrows to the During Force panel to show the strength and direction of the forces that are exerted on each object during the collision.

Name: _____ Date: _____

Exploring Direction of Collision Forces

Collisions with One Moving Object

Experimental Setup Part 1: Top View



15 cm

What are forces like in a collision? Use the data table to set up the collisions and record the results.

1. Use the image as an example to set up your objects.
2. Roll Object A toward Object B and observe how the objects change velocity when they collide. Record your observations in the data table for Effect: Object A and Effect: Object B. Choose from the following options:
   - **speed up, slow down, start moving, stop moving, change direction**
3. Based on the velocity changes, infer the direction of the force (if any) acting on each object and record it in the table for Force direction: Object A and Force direction: Object B. Choose from the following options:
   - **left, right, none**
4. Repeat these steps for all three collisions.
5. When the tests are complete, move on to the next part of the activity.

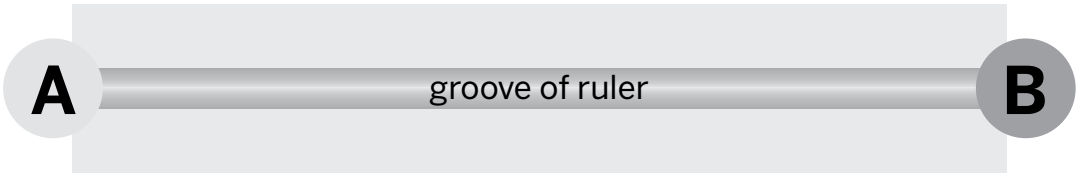
Collision	**Object A** (moving *right* before collision)	**Object B** (NOT moving before collision)	**Effect: Object A**	**Effect: Object B**	**Force direction: Object A**	**Force direction: Object B**
1	rubber ball	rubber ball				
2	golf ball	rubber ball				
3	rubber ball	golf ball				

Name: _____ Date: _____

Exploring Direction of Collision Forces (continued)

Collisions with Two Moving Objects

Experimental Setup Part 2: Top View



What are forces like in a collision? Use the data table to set up the collisions and record the results.

1. Use the image as an example to set up your objects.
2. Roll Object A and Object B toward each other, and observe how the objects change velocity when they collide. Record your observations in the data table for Effect: Object A and Effect: Object B. Choose from the following options:
   - **speed up, slow down, start moving, stop moving, change direction**
3. Based on the velocity changes, infer the direction of the force (if any) acting on each object and record it in the table for Force direction: Object A and Force direction: Object B. Choose from the following options:
   - **left, right, none**
4. Repeat these steps for the second collision.

Collision	**Object A** (moving *right* before collision)	**Object B** (moving *left* before collision)	**Effect: Object A**	**Effect: Object B**	**Force direction: Object A**	**Force direction: Object B**
1	rubber ball	rubber ball				
2	golf ball	rubber ball				

Name: _____ Date: _____

Exploring Strength of Collision Forces

What are forces like in a collision? Use the *Force and Motion* Simulation to gather evidence about the strength of the forces exerted during collisions between objects that have the same mass, then between objects that have different masses.

For Each Trial

1. Change the initial velocity of each object as described in your data table.
2. Press RUN and observe how the velocity of each object changes due to the collision. Record your observations in the data table. For the effect, choose from the following options:
   - **speed up, slow down, start moving, stop moving, change direction**
3. Press ANALYZE to determine the strength and direction of the force exerted on each object. Record in the data table.

Part 1: Objects with the Same Mass

Select **3.2 Same Mass Collisions** from the menu. Complete the steps for each trial.

Collision	Initial velocity: Object A	Initial velocity: Object B	Effect: Object A	Effect: Object B	Force strength/ direction: Object A	Force strength/ direction: Object B
Trial 1	5 cm/s right	0 cm/s				
Trial 2	5 cm/s right	2 cm/s left				
Trial 3	5 cm/s right	2 cm/s right				

Name: _____ Date: _____

Exploring Strength of Collision Forces (continued)

Part 2: Objects with Different Masses

Select **3.2 Different Mass Collisions** from the menu. Complete the steps on page 69 for each trial.

Collision	Initial velocity: Object A	Initial velocity: Object B	Effect: Object A	Effect: Object B	Force/ strength direction: Object A	Force/ strength direction: Object B
Trial 1	5 cm/s right	0 cm/s				
Trial 2	5 cm/s right	2 cm/s left				
Trial 3	5 cm/s right	2 cm/s right				

Part 3: Reflecting on Forces in Collisions

1. Discuss the hands-on activity with your partner: *What did you learn from this activity about the direction of forces in a collision?*
2. Discuss the Sim activity with your partner: *What did you learn about the strength of forces in a collision?*
3. Write a claim that describes the strength and direction of forces exerted on objects during a collision. Use at least four of the words from the word bank in your response.

Word Bank

collision	direction	force	velocity
same	strength	opposite	

What are the forces like in a collision?

_____

_____

_____

Name: _____ Date: _____

Discussing the Collision of the Pod and Space Station

Discuss these questions with your partner:

1. What can you infer about the strength and direction of forces experienced by the pod and space station when they collided? What evidence from today's activities supports your inference?
2. In a message from Dr. Gonzales, we learned that the space station is moving as a result of the collision. Say which direction you think it is moving and explain why.

Name: _____ Date: _____

Homework: Modeling Collision Forces

1. Open the *Force and Motion* Modeling Tool activity: Collision Forces.
2. Revise the model that you began in the Warm-Up so it reflects your current thinking.
3. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here:

   _____

Goal: Match the forces exerted when two objects collide (strength and direction).

Do: Drag force arrows to the During Force panel to show the strength and direction of the forces that are exerted on each object during the collision.

Name: _____ Date: _____

Lesson 3.3: Effect of Collisions

When objects collide, they may have different changes in velocity. What is it about the forces in a collision that can cause this effect? Is there something about the objects themselves? You will use evidence to draw conclusions about the characteristics of collision forces and return to the text to start figuring out why collisions can affect objects differently.

Unit Question

- How do forces affect motion?

Chapter 3 Question

- After the collision, how does the pod's motion compare to the motion of the space station?

Key Concepts

- When two objects collide, a force is exerted on each object. The two forces are exerted in opposite directions, but they are the same strength.

Vocabulary

- cause
- collision
- effect
- exert
- force
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Simulation

Name: _____ Date: _____

Warm-Up

In a collision, how do forces affect the objects?

Predict how forces will affect two objects that collide. (check one)

- ☐ I predict that both objects will change velocity.
- ☐ I predict that only one object will change velocity.
- ☐ I predict that neither object will change velocity.

Use the *Force and Motion* Simulation to gather evidence about how forces affect the objects in a collision.

1. Select **3.3 Warm-Up** from the Sim menu.
2. Record the mass of each object.
   - Mass of Object A: _____ kg
   - Mass of Object B: _____ kg
3. Run the test collisions:
   - Change the starting velocity of each object as described in your data table.
   - Press RUN to observe the collision.
   - Press ANALYZE to determine the change in velocity for each object.
   - Record your observations in the data table.
4. After you complete the three tests, discuss the reflection questions with your partner.

Collision	Initial velocity of Object A	Initial velocity of Object B	Object A: change in velocity	Object B: change in velocity
1	5 cm/s right	0 cm/s		
2	5 cm/s right	2 cm/s left		
3	5 cm/s right	2 cm/s right		

Reflection Questions

1. What do you notice about the change in velocity on the objects?
2. Why do you think the objects in each collision experienced a different change in velocity?

Name: _____ Date: _____

Rereading "Crash!"

Why are the effects of a collision between a bug and a car's windshield so different from the effects of a collision between two bugs?

Read paragraphs 3 and 4 of "Crash!" and then answer the questions. As you read, you may want to highlight or annotate parts of the text that could prove helpful.

1. What are the effects of the collision forces when objects with different masses collide?

_____

_____

_____

_____

2. What are the effects of the collision forces when objects of the same mass collide?

_____

_____

_____

_____

Name: _____ Date: _____

Word Relationships

1. Work with a partner and use the words on the cards to create sentences (either aloud or on scratch paper) that answer the prompt: **Why are the effects of collisions different if the force on each object is the same strength?**
2. Use at least two words from the word bank in each sentence. You don't have to use all the words.
3. Create as many sentences as you can. Try to use more than one sentence to express your ideas.
4. When you are finished creating sentences, join another pair and share your sentences.

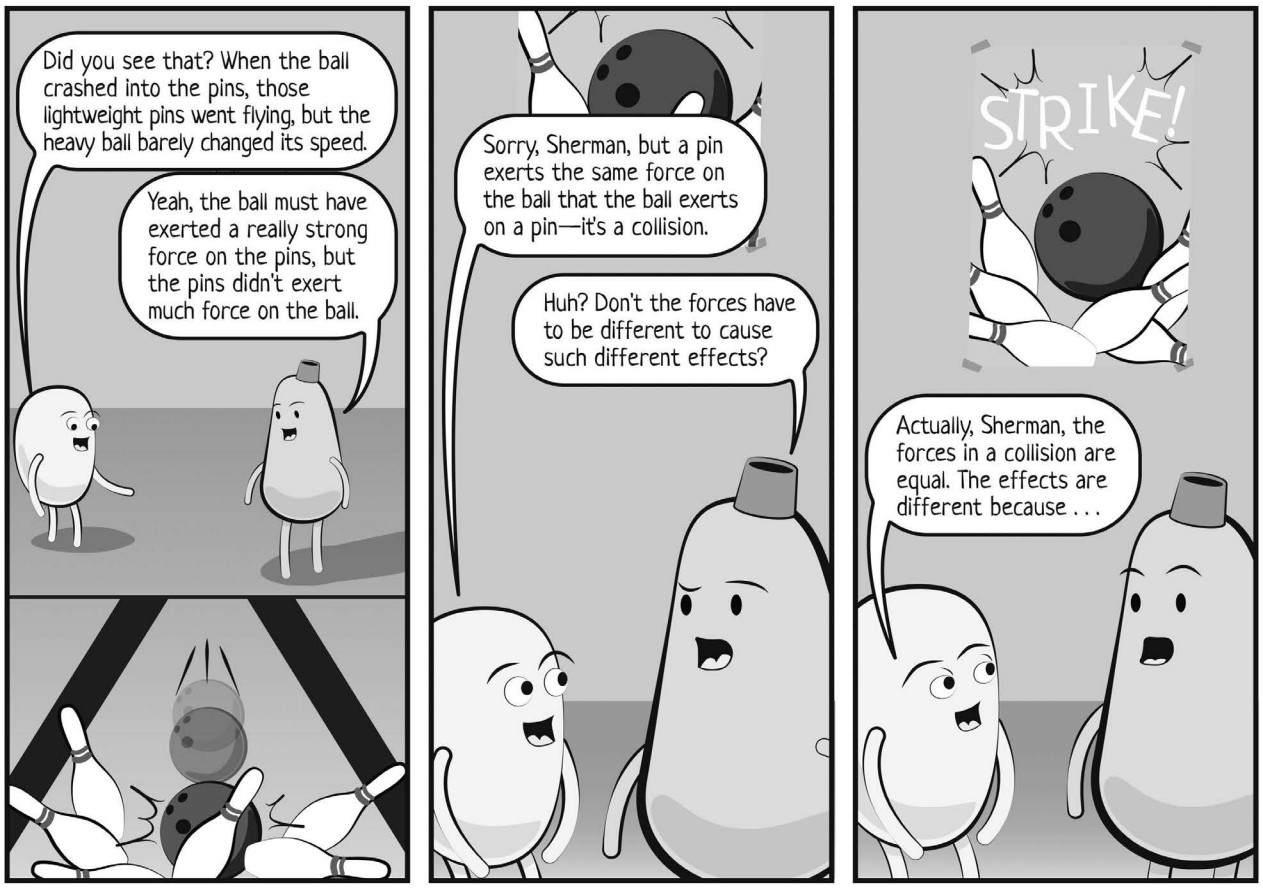
Word Bank

collision	force	mass	velocity

Name: _____ Date: _____

Homework: Sherman's Story: Collisions

Sherman's Story: Collisions



How would you finish the explanation to Sherman? Why do colliding objects of unequal mass experience different effects?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Wrecking Ball"

Read "Wrecking Ball." Annotate the article as you read. Then, answer the questions below.

1. Explain why a wrecking ball can destroy a building, but a yo-yo can't. Use the term *kinetic energy* in your explanation.

_____

_____

_____

_____

_____

_____

2. How is speed related to *kinetic energy*?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.4: Reasoning About the Pod's Motion

Is there still a chance that the ACM pod can be rescued? You now know that the strength of forces in a collision are the same, yet the effects are sometimes different. Today you'll need to determine how the collision affected the pod and space station. Is the pod moving faster, slower, or did it stay at the same speed as the space station after the collision? Is the pod still close enough to the space station that the space agency can plan a rescue mission?

Unit Question

- How do forces affect motion?

Chapter 3 Question

- After the collision, how does the pod's motion compare to the motion of the space station?

Key Concepts

- When two objects collide, a force is exerted on each object. The two forces are exerted in opposite directions, but they are the same strength.
- Even though the force exerted on each object in a collision is the same strength, if the objects have different masses, their changes in velocity will be different.

Vocabulary

- cause
- collision
- effect
- exert
- force
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Modeling Tool activity: Pod Collision

Name: _____ Date: _____

Warm-Up

Ana Gonzales
To: Student Physicists
Re: Pod and Space Station Data

UNIVERSAL SPACE AGENCY

You've done excellent work in investigating how collisions affect different objects, and we're looking forward to your final report.

In case you might find the following helpful for comparing the speed of the pod and the space station after the collision, here are their masses:

Pod: 1,100 kg **Space Station:** 415,400 kg

Regards,
Ana

Dr. Ana Gonzales, Program Scientist
Asteroid Collection Mission

How can you use this information about mass to help you compare the speed of the pod after the collision to the speed of the space station after the collision?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Introducing the Reasoning Tool

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Evidence A: The thruster force was the same strength as other missions and it was exerted in the opposite direction.		**Claim 2:** The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction.
Evidence B: The pod mass was 1,100 kg, 130 kg more than usual.		**Claim 2:** The thrusters only slowed the pod, it didn't stop; the pod hit the space station, which made it bounce and move in the opposite direction.

Name: _____ Date: _____

Reasoning About the Pod

After the collision, how does the pod's motion compare to the motion of the space station?

- **Claim 1:** The pod is moving faster than the space station.
- **Claim 2:** The pod and the space station are moving at the same speed.
- **Claim 3:** The pod is moving more slowly than the space station.

Read the evidence in the first column. Use the Reasoning Tool to reason about the evidence and evaluate the claims. Select a claim to support and explain how that claim is connected to the evidence.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Mass of pod: **1,100 kg** Mass of space station: **415,400 kg**		

Name: _____ Date: _____

Modeling the Pod's Collision

1. Open the *Force and Motion* Modeling Tool activity: Pod Collision.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here:

_____

Goal: Model the forces exerted when this pod and the space station collided. Show how the velocity of each object changed as a result of the collision.

Do:

- Show the locations of the pod and space station during and after the collision.
- Show the strength of the forces exerted on each object during the collision.
- Show the final velocities of the pod and space station.

Tips:

- The medium mass object represents the pod.
- The large mass object represents the space station.

Name: _____ Date: _____

Homework: Reporting to Dr. Gonzales

In your final report to Dr. Gonzales, use evidence to explain what happened during the missing seconds and compare the pod's motion to the space station's motion after the collision.

Use your completed Reasoning Tool, model, and suggested words and phrases to help with your explanations.

Word Bank

cause	collision	effect	exert
force	mass	strength	velocity

Cause-and-Effect Words and Phrases

if . . . , then	because	as a result	this led to . . .
when	therefore	next	

Part 1: What happened to the pod during those seconds when communication was lost?

_____

_____

_____

_____

_____

_____

Part 2: After the collision, how does the pod's motion compare to the motion of the space station?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the ACM pod during the time when Mission Control lost contact?

1. I understand how forces could have caused the pod to move in the opposite direction. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

2. I understand how something about the pod could have affected its velocity change. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

3. I understand the forces in a collision, which is the moment when two objects hit each other. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

4. I understand why the objects in a collision can have different changes in motion. (check one)

   ☐ yes ☐ not yet

   Explain your answer choice. _____

   _____

5. What do you still wonder about force and motion as they relate to the Asteroid Collection Mission that did not go as planned?

   _____

   _____

Name: _____ Date: _____

Chapter 4: Force, Motion, and Movie Sets
Chapter Overview

Dr. Gonzales's niece, a student film director named Claire, has contacted you asking for help with a scene in her movie. She is filming on a miniature set, and she can't get the collision scene to work out like the one she saw in the movie, *Iceworld Revenge*. She would like your help in figuring out why one of her vehicles fell off the cliff after the collision, but the vehicle in the movie did not.

Name: _____ Date: _____

Lesson 4.1: Using Physics on Movie Sets

A student film director has heard about your work for Dr. Gonzales and she has asked for your help with a crash scene in a movie that she is directing. Would you please use your understanding of the relationship between force, mass, and velocity change to help her figure out why her attempt at recreating a collision in a movie scene was unsuccessful?

Unit Question

- How do forces affect motion?

Chapter 4 Question

- Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film *Iceworld Revenge*?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.
- A stronger force can cause a greater change in velocity.
- Understanding a cause-and-effect relationship can help you infer what led to a particular result.
- If the same strength force is exerted on two objects but the objects have different masses, the object with less mass will have a greater change in velocity.
- When two objects collide, a force is exerted on each object. The two forces are exerted in opposite directions, but they are the same strength.
- Even though the force exerted on each object in a collision is the same strength, if the objects have different masses, their changes in velocity will be different.

Vocabulary

- cause
- collision
- effect
- exert
- force
- friction
- infer
- mass
- velocity

Name: _____ Date: _____

Warm-Up

1. Turn to your partner and share what you remember about friction. List your ideas.

_____

_____

_____

_____

2. Your teacher will show you a video about friction. As you watch, listen carefully and think about the reflection questions on the board.

Name: _____ Date: _____

Introducing Movie Sets and Claire's Problem

Claire Gonzales
To: Student Physicists
Re: Help for Miniature Movie Set

CG

I'm a film student at Midvale University and I heard from my aunt, Dr. Ana Gonzales, that your experience with force and motion helped in figuring out what happened to the pod that didn't dock with the space station. I'm hoping you might be able to help me!

I saw a thrilling car crash scene in *Iceworld Revenge* and I want to show something similar in the movie I'm making for my final project. Vehicle 1 speeds along an icy surface in *Iceworld Revenge.* Vehicle 2 looks exactly the same, and it's parked at the edge of a cliff. Vehicle 1 collides with Vehicle 2, but Vehicle 2 does not fall off the cliff! It looked so cool in the movie and added lots of drama to the scene. I want this in my movie!

I know the collision in *Iceworld Revenge* was filmed with miniature cars and a miniature set, but when I tried to film the scene, it didn't work. Vehicle 2 shot right off the cliff! I analyzed the scene in *Iceworld Revenge*, hoping to understand what they did. I'm attaching all the information I have. Please help me figure out why my test didn't work!

Thanks in advance,
Claire

Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film *Iceworld Revenge*?

- **Claim 1:** The vehicles in *Iceworld Revenge* had different masses; in Claire's test, the vehicles had the same mass.
- **Claim 2:** The friction of the surface that was used in *Iceworld Revenge* was different from the friction of the surface in Claire's test.

Name: _____ Date: _____

Analyzing Evidence from the Film Student

Examine each evidence card. Annotate the cards to help you think about the evidence. Then, use the following questions as a guide for discussing each card with your partner.

- What questions do you have about the information on the card?
- What does the evidence tell you about how the force of friction might have affected each car's velocity change?
- What does the evidence tell you about how the mass of each car might have affected its velocity change?

Name: _____ Date: _____

Coordinating Claims and Evidence

1. With a partner, discuss whether each piece of evidence supports or goes against a claim. Use the sentence starters to help you talk with your partner.
2. Make annotations on each card:
   - If the evidence supports a claim, write SUPPORTS CLAIM ***(1 or 2)*** on that card.
   - If the evidence goes against a claim, write GOES AGAINST CLAIM ***(1 or 2)*** on that card.
   - If the evidence connects with another evidence card, write CONNECTS WITH EVIDENCE CARD ***(A or B)*** on that card.
3. Sort the evidence by placing the cards underneath the claim they support.

Sentence Starters

- I think this piece of information supports this claim because . . .
- I don't think this piece of information supports this claim because . . .
- I agree because . . .
- I disagree because . . .
- Why do you think that?

Name: _____ Date: _____

Lesson 4.2: Discussing Physics and Movie Sets

Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film *Iceworld Revenge*? Today you'll discuss two possibilities: It could be that in *Iceworld Revenge,* the vehicles had different masses, while in Claire's test they were the same mass, OR that the surface the vehicles ran on in *Iceworld Revenge* provided a different amount of friction than the surface that Claire used for her vehicles. You'll be using what you know about force, velocity, mass, and collisions to build a convincing argument. Through this discussion, you will either help change your classmates' minds about the claims or change your own mind.

Unit Question

- How do forces affect motion?

Chapter 4 Question

- Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film *Iceworld Revenge*?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.
- A stronger force can cause a greater change in velocity.
- Understanding a cause-and-effect relationship can help you infer what led to a particular result.
- If the same strength force is exerted on two objects but the objects have different masses, the object with less mass will have a greater change in velocity.
- When two objects collide, a force is exerted on each object. The two forces are exerted in opposite directions, but they are the same strength.
- Even though the force exerted on each object in a collision is the same strength, if the objects have different masses, their changes in velocity will be different.

Vocabulary

- cause
- collision
- effect
- exert
- force
- friction
- infer
- mass
- velocity

Name: _____ Date: _____

Warm-Up

Look back at the evidence cards in your envelope and review the annotations. Use the evidence cards to answer the questions.

Science Seminar Question: *Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film* Iceworld Revenge*?*

Which claim do you think is more convincing? (check one)

☐ **Claim 1:** The vehicles in *Iceworld Revenge* had different masses; in Claire's test, the vehicles had the same mass.

☐ **Claim 2:** The friction of the surface that was used in *Iceworld Revenge* was different from the friction of the surface in Claire's test.

1. Draw a star on the evidence card that best supports the claim you selected.
2. Why did you choose this piece of evidence? How does it support the claim?

_____

_____

_____

_____

_____

_____

3. Be prepared to discuss your ideas with a partner.

Name: _____ Date: _____

Preparing for the Science Seminar

1. Take turns with your partner: share which claim you think is more convincing.
2. Use your Warm-Up responses and the Scientific Argument Sentence Starters to help you share ideas.
3. Refer to the annotated claims and evidence cards in your envelope, as needed.

Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film Iceworld Revenge*?*

☐ **Claim 1:** The vehicles in *Iceworld Revenge* had different masses; in Claire's test, the vehicles had the same mass.

☐ **Claim 2:** The friction of the surface that was used in *Iceworld Revenge* was different from the friction of the surface in Claire's test.

Name: _____ Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is: _____ _____ _____ _____	

Name: _____ Date: _____

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, think back on your claim. After participating in the discussion, you may have changed your mind about which claim you think is best supported by the evidence. Explain your current thinking by answering the questions.

Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film Iceworld Revenge*?*

Which claim is more convincing? (check one)

☐ **Claim 1:** The vehicles in *Iceworld Revenge* had different masses; in Claire's test, the vehicles had the same mass.

☐ **Claim 2:** The friction of the surface that was used in *Iceworld Revenge* was different from the friction of the surface in Claire's test.

Did the Science Seminar cause your thinking about the claims to change? Explain.

_____

_____

_____

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Name: _____ Date: _____

Lesson 4.3: Writing a Scientific Argument

It's time to make your final scientific argument! You've studied force and motion and discussed the claims and evidence that will help you determine why Vehicle 2 fell off the cliff in Claire's test but did not in *Iceworld Revenge*. Now, it's time for you to make your case in writing. Today, you'll review the evidence and use the Reasoning Tool to organize your thinking. Then you'll write a scientific argument to Claire, focusing on *why*. You will also have the opportunity to investigate kinetic energy and how it relates to the motion of objects.

Unit Question

- How do forces affect motion?

Chapter 4 Question

- Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film *Iceworld Revenge*?

Key Concepts

- A force is required to change the velocity of an object.
- How an object changes velocity depends on the direction of the force exerted on that object.
- A stronger force can cause a greater change in velocity.
- Understanding a cause-and-effect relationship can help you infer what led to a particular result.
- If the same strength force is exerted on two objects but the objects have different masses, the object with less mass will have a greater change in velocity.
- When two objects collide, a force is exerted on each object. The two forces are exerted in opposite directions, but they are the same strength.
- Even though the force exerted on each object in a collision is the same strength, if the objects have different masses, their changes in velocity will be different.

Vocabulary

- cause
- collision
- effect
- exert
- force
- friction
- infer
- mass
- velocity

Digital Tools

- *Force and Motion* Simulation

Name: _____ Date: _____

Warm-Up

Reasoning connects evidence to a claim. Sometimes, you can support two different claims with the same evidence by using different reasoning. Complete the center column in each Reasoning Tool so the same evidence supports a claim that running **causes** injury and that running **prevents** injury.

1. Use reasoning so the evidence supports a claim that running **causes** injury.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Running puts more pressure on the knee joint and makes muscles work harder than walking.		Running causes injury.

2. Use reasoning so the evidence supports a claim that running **prevents** injury.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Running puts more pressure on the knee joint and makes muscles work harder than walking.		Running prevents injury.

Name: _____ Date: _____

Using the Reasoning Tool

Use the Science Seminar Reasoning Tool sheet to explain how the evidence supports your claim. Follow the instructions below.

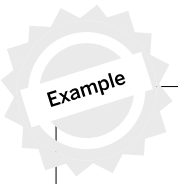
1. Record the claim that you think is best supported by the evidence (in the Therefore, column). If you prefer, you can also write and record your own claim.
2. Tape the evidence cards that support your claim to the Reasoning Tool (in the Evidence column). You do not need to use all the cards, but you can use more than one to support your claim.
3. Use the middle column (This matters because . . .) to record how the evidence in the left column connects to the claim in the right column.

Name: _____ Date: _____

Preparing to Write

Organizing Your Reasoning Tool

- Draw a circle around your strongest piece of evidence.
- Draw an X over a piece of evidence if you do not plan to use it in your argument.
- Draw an arrow to connect two pieces of evidence if you think that they go together.



Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Name: _____ Date: _____

Writing a Scientific Argument

Write your scientific argument to Claire. As you write,

- review your Reasoning Tool. Include your strongest piece of evidence and make connections between pieces of evidence that go together; and
- use the Scientific Argument Sentence Starters to help write sentences that clearly explain your thinking.

Scientific Argument Sentence Starters

Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If _____, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since _____, . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Write a scientific argument that addresses this question: *Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film* Iceworld Revenge*?*

Claim 1: The vehicles in *Iceworld Revenge* had different masses; in Claire's test, the vehicles had the same mass.

Claim 2: The friction of the surface that was used in *Iceworld Revenge* was different from the friction of the surface in Claire's test.

State your claim. Use evidence to support your claim, and then explain how the evidence supports your claim.

_____

_____

_____

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_____

_____

_____

Name: _____ Date: _____

Writing a Scientific Argument (continued)

Name: _____ Date: _____

Homework: Revising an Argument

1. Reread the scientific argument you wrote in class.
2. Complete your argument, if needed.
3. Look for ways that you could make your argument clearer or more convincing.
4. Consider reading your argument aloud or having another person read it.
5. Ask yourself these questions as you review your argument:
    - Does this argument clearly state a claim?
    - Did I describe the supporting evidence?
    - Did I thoroughly explain how the evidence supports the claim?
6. Rewrite any sections of your argument that could be clearer or more convincing.

Write a scientific argument that addresses this question: *Why did Vehicle 2 fall off the cliff in Claire's test of the collision scene, but Vehicle 2 did not fall off the cliff in the film* Iceworld Revenge*?*

- State your claim.
- Use evidence to support your claim.
- Explain how the evidence supports your claim.

Name: _____ Date: _____

Homework: Revising an Argument (continued)

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

1. I understand that scientists connect evidence to their claims to make stronger arguments. (check one)

   ☐ yes ☐ not yet

Explain your answer choice. _____

_____

2. What are the most important things you have learned in this unit about how forces affect motion?

_____

_____

_____

_____

_____

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

Force and Motion Glossary

cause: an event or process that leads to a result or change
causa: un evento o proceso que provoca un resultado o cambio

collision: the moment when two objects hit each other
colisión: el momento cuando dos objetos chocan entre sí

effect: a result or change that happens because of an event or process
efecto: un resultado o cambio que ocurre debido a un evento o proceso

equal: the same in quantity, size, degree, or value
igual: lo mismo en cantidad, tamaño, grado o valor

exert: to apply a force
ejercer: aplicar una fuerza

force: a push or a pull that can change the motion of an object
fuerza: un empujón o un jalón que puede cambiar el movimiento de un objeto

friction: a force between an object and the surface it is moving over
fricción: una fuerza entre un objeto y la superficie sobre la cual se está moviendo

infer: to reach a conclusion using evidence and reasoning
inferir: llegar a una conclusión usando evidencia y razonamiento

kinetic energy: the energy that an object has because it is moving
energía cinética: la energía que tiene un objeto porque se está moviendo

mass: the amount of matter that makes up an object
masa: la cantidad de materia que forma un objeto

matter: anything that has mass and takes up space
materia: cualquier cosa que tenga masa y ocupe espacio

opposite: acting or going in the reverse direction
opuesto: que actúa o va en la dirección inversa

pod: a self-contained unit on an aircraft, spacecraft, vehicle, or vessel that can be detached for a particular function

compartimento desprendible: una unidad autónoma en una aeronave, nave espacial, vehículo o embarcación que se puede desprender para realizar una función específica

speed: how fast an object is moving

rapidez: qué tan deprisa se está moviendo un objeto

velocity: speed in a particular direction

velocidad: rapidez en una dirección particular

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Force and Motion:

Docking Failure in Space

Article Compilation

Table of Contents: Articles

On ice, a hockey puck can travel a long way with just one push.

Friction

Why Hockey Rinks Are Not Carpeted

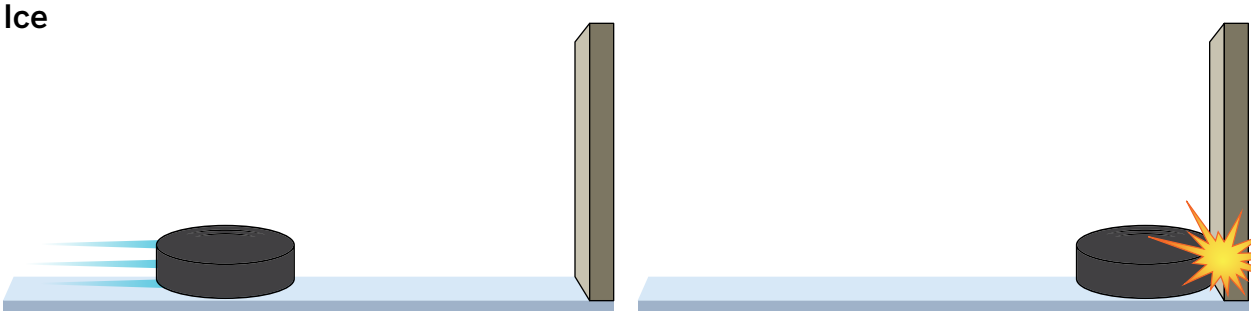
If you've ever slid a hockey puck across an ice rink, you know that it can travel a long way with just one push. In fact, if you don't touch it, the puck might go so far that it doesn't stop until it hits something like a wall! If you try the same thing on carpet, you'll find out that there's a reason nobody plays hockey on carpet: the puck doesn't go very far on a single push. If you hit it with a hockey stick and then don't touch it, the puck slides across the carpet a bit, slows down, and then stops. What happened? Since the velocity of the puck changed, there must have been a force acting on it. That force is friction, the force that slows objects down as they move across surfaces.

Why does friction cause objects to slow down? Friction is a force that acts in the opposite direction of an object's movement. Surfaces that are rough or sticky tend to have a lot of friction when an object moves across them. Surfaces that are smooth tend not to have a lot of friction. That's why the hockey puck moves much farther with one push across ice than across a carpeted floor—carpet is rougher than ice.

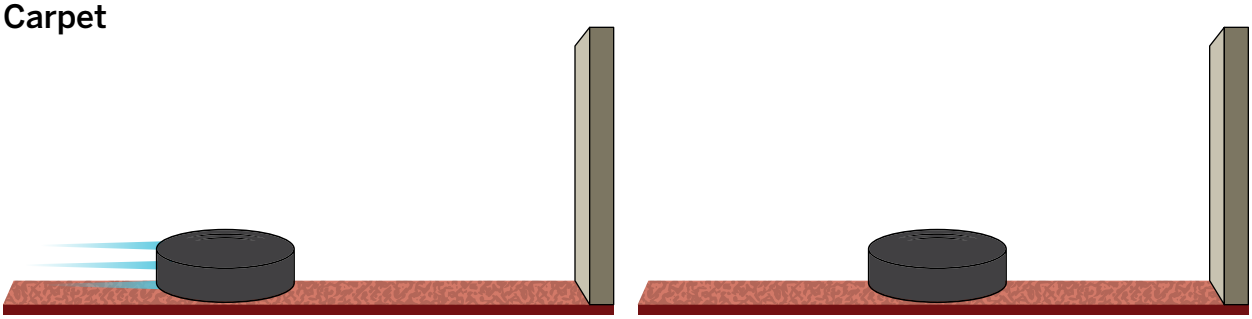
There's one place where there is no friction at all to slow things down: space! On Earth, there is some friction caused by the air in the atmosphere. This friction is known as air resistance. However, in space, there is no air. Therefore, there's no air resistance, and an object that starts moving will keep going forever—unless a force is exerted upon it, such as when it collides with something.

Motion of a Hockey Puck on Ice vs. Carpet

Ice



Carpet



A hockey puck travels much farther on ice than on carpet because ice exerts much less friction on the puck than carpet does.

People use wheelchairs for lots of different activities, and wheelchairs come in many styles.

Designing Wheelchairs for All Shapes and Sizes

People who use wheelchairs come in all different shapes and sizes—children and adults, tall and short, big and small—and so do the wheelchairs they use. Some wheelchairs have motors, and others are operated by hand. People who use wheelchairs do all kinds of different things. Wheelchair users may go to school or work in an office. They may sing in a rock band, take their dogs to the park, compete in races, or lead a parade through city streets.

Dr. Rory Cooper designs wheelchairs and other technologies for people with disabilities. Here, he demonstrates a robotic arm that attaches to a wheelchair and helps its user grasp items from far away.

Wheelchairs are designed for the people who use them and for the different activities they want to do. Dr. Rory Cooper knows all about designing wheelchairs: he's an engineer who works to improve wheelchair safety, comfort, and usefulness. He and his team design wheelchairs for many different purposes, from world-class racing and other sports to everyday mobility.

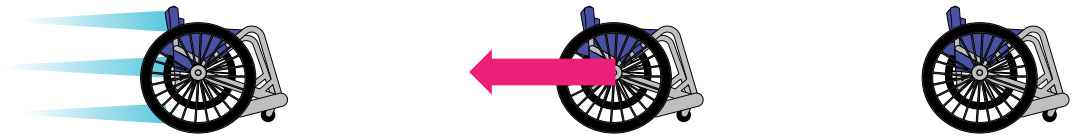
Dr. Cooper served in the United States Army. During his service, he was injured and began using a wheelchair. After he left the military, he went to college and studied engineering. Today, Dr. Cooper runs the Human Engineering Research Labs (HERL) at the University of Pittsburgh, Pennsylvania. There, he works with other scientists on technologies that help people with disabilities. Dr. Cooper is also an athlete: he won a bronze medal in wheelchair racing at the 1988 Paralympics. The Paralympics are a series of athletic events for people with disabilities. They take place just after the Olympics and in the same location as the Olympics.

Dr. Cooper designs each wheelchair to fit the person who will be using it and the activities it will be needed for. One way he and his team can change the design of a wheelchair is by changing the mass of the chair. Mass is the amount of matter that makes up an object—on Earth, objects with more mass are heavier than objects with less mass. By changing the mass of a wheelchair, Dr. Cooper can make it change velocity more easily or less easily. That makes each chair useful for certain activities. For example, some wheelchairs are built especially for playing different sports.

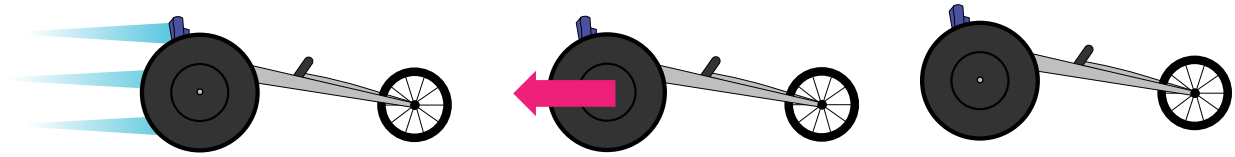
Wheelchairs used for wheelchair racing are built for speed. That means they need to be light. Lighter chairs change velocity more easily than heavier ones, so it's easier for a racer to go from sitting still to racing speed in a light chair. It also takes less force from the racer to stop a light chair than it takes to stop a heavy chair. Dr. Cooper's racing wheelchairs are made of materials that are light and strong, so the racer can start the race and speed up as quickly as possible using the least possible force.

Not all athletes in wheelchairs want to change velocity easily. Another popular sport that

Rugby wheelchair design



Racing wheelchair design



The strength of force needed to stop a quickly moving wheelchair will vary depending on how massive the wheelchair is. Rugby wheelchairs take more force to stop than those used in racing because they are more massive.

uses wheelchairs is wheelchair rugby, a fast, full-contact sport played on a court similar to a basketball court. Wheelchair rugby players need stability—they crash into each other often, and it's important that they don't tip over in a collision. For this reason, rugby wheelchairs are heavier than racing wheelchairs. Their weight means players need to use more force to get them moving when they're stopped and to make them stop moving once they get going, but it also means they aren't affected as much by the forces involved in collisions, so they are less likely to fall over during a crash. Rugby players in heavy, stable wheelchairs are more likely to stay upright and play successfully for their teams.

Designing wheelchairs with less mass for racing and wheelchairs with more mass for sports like rugby is just one example of how wheelchairs can be designed for different users and activities. When engineers design wheelchairs, the most important consideration is the person who is using the chair. A smaller person needs a different wheelchair than a larger person. Some wheelchair users turn the wheels of their chair by hand, while others use chairs with electric motors. Some wheelchair users are able to operate their chairs simply by moving their eyes. Wheelchair users choose chairs that work for their needs, fit their budget, and suit their own personal styles.

Wheelchairs come in many types—and thanks to Dr. Cooper's work at HERL, wheelchair users have more options than ever before.

Wheelchairs built for racing need to be light. The less mass the chairs have, the farther they can go on a single push.

The heavy wheelchairs used for wheelchair rugby are very stable. Even when they run into each other, they are hard to tip over.

Some people use special wheelchairs to play tennis. These wheelchairs are light, strong, and easy to adjust quickly for different types of matches.

When a car hits a bug, both the car and the bug experience the same forces. However, those same forces have a much greater effect on the bug because its mass is so much less than the mass of the car.

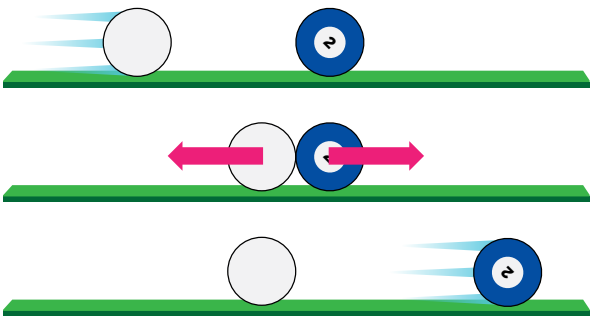
Crash!

Forces in Collisions

Say you're in a car driving down the highway at 60 miles per hour, and...SPLAT! Your car hits a bug. It probably seems like all the force of that collision acted on the bug. After all, the bug is splattered across your windshield, but you and the car probably didn't feel a change. However, not all collisions result in such different results. When two bugs that are about the same size fly into each other, the effect on both bugs is similar: they're both bumped off course by about the same amount. How can some collisions affect objects the same way (like the two bugs) and other collisions have vastly different effects (like the bug splattered on the car windshield)? The world is full of things running into each other, and what happens as a result of those collisions depends on the physics of force, mass, and velocity. Below, you'll read about everyday examples of how collisions affect objects around us.

How to Stop a Pool Ball

In a game of pool, also known as billiards, you hit a white cue ball with a long stick called a cue. You want the cue ball to knock other balls, sitting stationary on the pool table, into the pockets on the edges of the table. However, you don't want the cue ball to follow them into the pockets. Hitting the cue ball can be risky! Whether they know it or not, pool players use physics to their advantage: if they set up the collision just right, the cue ball comes to a complete stop after the collision, while the colored ball starts moving. How does that work? During a collision, both balls experience the same force, but in opposite directions. When a moving object collides in a straight line with an object of the same mass that's sitting still, both objects experience the same amount of force. However, the motion of the balls changes in different ways because of their initial velocity and the direction of the force on them. The moving object changes its velocity by going from motion to rest, while the still object goes from rest to motion with the same velocity the moving object used to have. Since the force is experienced by both balls, but in different directions, the colored ball moves across the table while the cue ball stops. That gives you the chance to win the game!

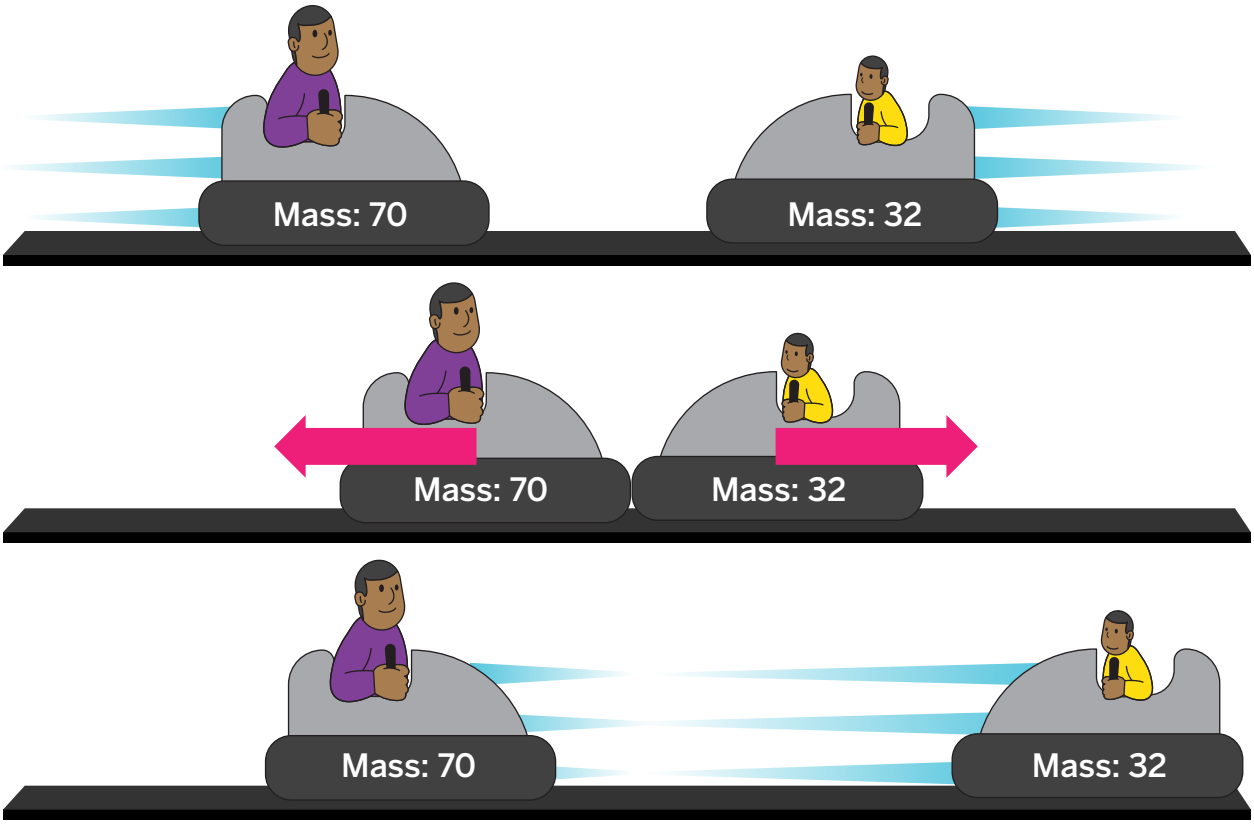


When two pool balls collide, both balls experience the same amount of force, but in opposite directions. Because they have the same mass, the ball that is moving stops, while the ball that is sitting still begins to move.

Pool players can use physics to make the balls on the table go where they want them to.

Bump!

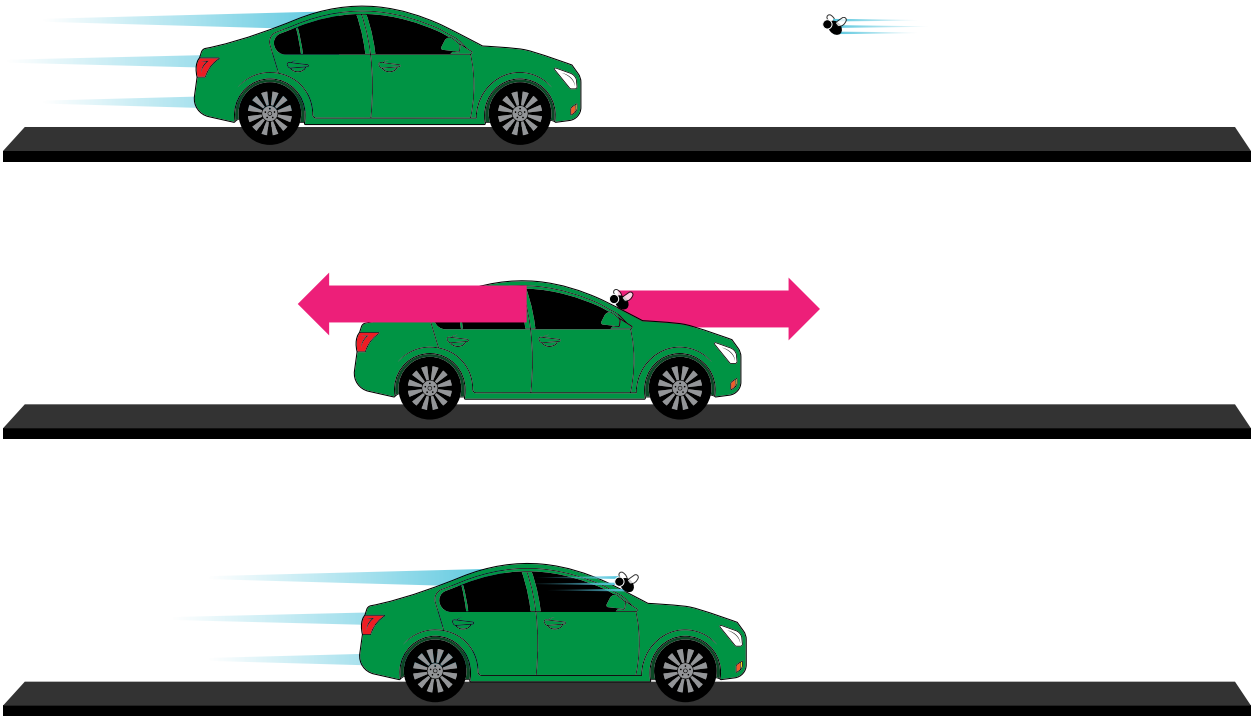
If you've ever driven a bumper car at a carnival or fair, you've already studied your fair share of collisions. After all, bumping into other cars is the whole point of bumper cars—it's right there in the name! If you and your bumper car bump into a car carrying a friend who's about the same size as you are, you might expect that both of you would experience equal forces. You have about the same amount of mass and are about the same size, so if you're both already moving, you bounce away from each other to about the same distance. But what if you bump into somebody with a different mass? Say you bump into your little brother, who has less mass than you do. You bounce back just a little bit, but your brother and his bumper car go zooming across the floor. Would you believe that the forces you experienced during the collision are still exactly the same? They are! Your brother moved far away from you because he has less mass than you do—the amount of force you both experienced was enough to send him flying at high speed. You didn't travel as far as he did because you have more mass. The effect of that same amount of force was only enough to change the velocity of your mass a small amount.



When a bumper car carrying a person with a lot of mass collides with a bumper car carrying a person without much mass, both bumper cars and both people experience the same forces. However, those forces have a stronger effect on the person with less mass, sending him or her zooming across the floor.

When two bumper cars collide, both cars experience the same amount of force. How each car responds after the collision depends on how much mass each rider has.

The distribution of forces in a collision between your car and a bug isn't so different from the forces in a collision between your bumper car and your brother's—in both collisions, both objects (or people) experience equal forces. It's the difference in the masses of the objects or people that makes the effects of the collisions dramatically different. Since the bug is so tiny, the effect of the collision with the windshield is large enough to suddenly change its velocity by a lot—so much that it ends up exploding on the windshield. Nothing so terrible happens to your brother in the bumper car when you run into him, though—your mass and his mass aren't very different, so the effects of the equal forces your collision produces affect you only slightly differently.



However, those same forces have a much greater effect on the bug because its mass is so much less than the mass of the car.

A wrecking ball like this one can knock a building down quickly.

Wrecking Ball

When a building becomes unsafe for people to use, or just isn't wanted anymore, a demolition company usually comes and tears down the building. This makes room for another use for the land. One way to tear down a building is to use a wrecking ball, a massive steel ball that swings from a chain attached to a tall crane. When the wrecking ball collides with a building, it breaks the walls of the building into pieces. A single hit from a wrecking ball can destroy a large part of a building.

However, setting up a wrecking ball isn't so simple: because wrecking balls are so massive, they can be difficult and expensive to move from place to place. They also make a big mess, throwing dust and pieces of building all over. So why do we use them? Compared to older ways of tearing down buildings, wrecking balls are speedy and efficient. (Before the invention of the wrecking ball in the 1800s, people used to tear buildings down brick by brick and board by board, which wasn't speedy or efficient at all. Wrecking balls are used less often today than they used to be, but are still used to destroy some buildings.)

What makes wrecking balls so good at what they do? Let's compare a wrecking ball with a toy yo-yo. A yo-yo is shaped like a wrecking ball but is much, much smaller and less massive. Say you swing the yo-yo into the side of a building, just like a crane would swing a wrecking ball. The collision wouldn't have very noticeable effects on the building OR the yo-yo: the yo-yo would just bounce off the wall, and the wall would probably stay just as it was. Why does a collision with a wrecking ball knock a

A swinging wrecking ball has a lot of kinetic energy—enough to break up a massive building

wall down, but a collision with a yo-yo doesn't? The difference is all in the size and mass of the wrecking ball—the thing that makes it hard to move is exactly what makes it good for knocking things down.

Making any kind of big physical change, like destroying a massive object, takes a lot of energy. This is certainly true of buildings: since they are big and have a lot of mass, it takes strong forces to knock them down. The forces produced by a collision with something massive, like a 5,443-kilogram (12,000-pound) wrecking ball, are stronger than the forces produced by a collision with something of a similar shape but much less mass, like a 0.05-kg (2-ounce) yo-yo. That's because collision forces transfer kinetic energy, or motion energy, from one object to another. The kinetic energy transferred to the wall is what causes the wall to break apart.

The more kinetic energy an object has, the more energy it can transfer to another object, and the stronger the force of a collision with it will be. Kinetic energy is related to the mass of the objects: as the the mass of an object grows, its kinetic energy grows by the same amount. Kinetic energy is also related to speed. When the speed of an object increases, its kinetic energy becomes much greater. In fact, kinetic energy grows by the square of the speed of an object. This means that if an object doubles in speed, then its kinetic energy is four times greater than it was before the increase in speed. If an object's speed increases by three times, its kinetic energy is now nine times greater! Even though speed is important to kinetic energy, a yo-yo would have to be moving VERY fast to have as much kinetic energy as a wrecking ball, because a wrecking ball is so much greater in mass. The massive wrecking ball has enough kinetic energy to break up nearly any building, leaving space for something new.

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