National Aeronautics and Space Administration

Friction

Educator Notes

Learning Objectives

- Identify the difference between static and kinetic friction.
- Predict the relative amounts of friction between several types of surfaces.
- Experiment with different objects and surfaces, observing the friction between each.

Safety

- Students will be able to slide objects down ramps. Instruct students to ensure objects stay on the ramp and to stand clear of objects as they reach the bottom of the ramp.

Introduce the Challenge

Background

In the STEMonstration video linked below, two of the types of friction discussed are static and kinetic. Static friction is a force that opposes the motion of two objects in contact with each other while they are motionless, such as trying to push a heavy box resting on the floor. The box resists being pushed until there is enough force to overcome the static friction and allow it to move. Kinetic friction is a force that opposes the motion of objects in contact with each other while one is moving past the other. In our scenario, once the static friction is overcome and the box begins to move, kinetic friction will still oppose the motion of the box. However, it takes less force to keep the box moving than it did to initially move the box because the force of static friction is always greater than kinetic friction. This is why antilock brakes are important. When heavy braking is applied to a vehicle, if a wheel locks up and skids, it no longer has the greater frictional force of static friction, but only the lesser frictional force of kinetic friction. In modern vehicles, sensors detect if a wheel locks up under heavy breaking and automatically decrease brake power to temporarily allow the wheel to gain traction and the full force of static friction.

STEMonstration video

- Show your students the STEMonstration: Friction video found at: https://www.nasa.gov/stemonstrations.
- Pose the following questions to students and facilitate a class discussion about each one:
  - How does static friction differ from kinetic friction?
  - Can both static friction and kinetic friction occur between the same two surfaces?
  - What are the properties of materials that will affect how much friction will occur between them and other materials?
  - Do you think static friction or kinetic friction is stronger? Why? Give examples.

Grades 6 to 8 Suggested Pacing

45-60 minutes

Materials

This list of materials supports one group of students.

- Friction Student Worksheet.
- 24-36-inch-long sturdy flat surface to make a ramp, such as a foam or cardboard presentation board.
- Protractor.
- Three various small items with a flat bottom, such as books, blocks, plastic containers, etc.
- Two sheets of an additional material long enough to cover one side of the ramp, such as aluminum foil, craft paper, wax paper, or gift-wrapping paper.
- Tape.

Next Generation Science Standards

- NGSS MS-PS2-2

Facilitate the Challenge

Make Predictions

- Split students into groups of three or four and provide each group with materials listed in the materials list.
- Explain to the students that they will be conducting nine different tests to observe the friction between the surfaces of the three small items provided as well as the three types of ramp surfaces (the plain surface and the two additional surfaces that they will use to cover the ramp).
- Instruct the teams to observe their three small objects and the three types of ramp surfaces and record the following predictions in their student worksheets:
  - Which combination of item and ramp surface will have the largest amount of static friction? Why?
  - Which combination of item and ramp surface will have the least amount of static friction?

Test

- Instruct the students to begin by placing their bare ramp, with no additional covering, flat on the floor or on a sturdy table. They will then place one of their small items at one end of the ramp and place the protractor vertically at the other end, aligning the zero-degree mark with the end of the ramp.
- Students will test the static friction between the two surfaces by slowly elevating the end of the ramp with their small item on top. As one student slowly raises the ramp, another should hold and observe the protractor, keeping track of the degree of angle of the ramp. A third student should observe the small item as their teammate raises the ramp and alert the other team members the moment when the object begins to slide down the ramp. The student worksheet contains a table for the students to record the angle of the ramp at the point the object begins to slide. Students should perform three test trials and find the average.
- After performing the test for each of the three small objects on the bare ramp, students will use tape to cover their ramp with one of the two other materials, giving their ramp a different surface with different friction properties.
- Students will then repeat the tests for all three of their small objects, recording their results in the student worksheet.
- Finally, students will cover their ramp with the third material and repeat the tests with each of their three small objects.
- After completing the experiment, have the groups answer the questions at the end of the student worksheet.

Share

- Allow each group to share their findings with the class, including the answers to the questions at the end of the student worksheet. Hold a classroom discussion with the class, posing some of the following questions:
  - If gravity was pulling your objects down the ramp, in what direction was the friction acting on your objects?
  - As you raised your ramps, static friction held your objects in place until the ramp was at a steep enough angle that static friction could no longer hold them. When the objects began to slide down the ramp, was static friction still affecting them? If not, what kind of friction was affecting them?
  - When the objects began to slide down the ramps, did they slide all the way, or did they stop partway? What does this say about the difference between static friction and kinetic friction? Which of the two frictional forces is stronger?
  - If two identical cars traveling at the same velocity both slam on their brakes quickly, and the wheels of one car locked causing the car to skid, which of the two cars will stop more quickly? Does this scenario help you understand why anti-lock brakes in vehicles help them slow down faster?
  - After performing this experiment, what properties of materials do you think would either increase or decrease their friction?

Extension

- Have students wrap their small objects in the same materials used to cover the ramps to experiment with friction between similar surfaces.
- Have students identify and test small objects in the environment with the greatest or least friction, such as a shoe, eraser, plastic pencil box, etc.
- Explore ways to increase or decrease friction between surfaces using various materials, such as cornstarch, oils, or water.
- Have students use a container on their ramp that they can fill with different amounts of mass to see if changing the mass of the object on the ramp changes the angle at which it begins to slide.

Friction
Student Worksheet

Introduce the Challenge

In this scientific investigation, you will explore the static friction between various surfaces. Use three small objects to place on a ramp. You will slowly increase the angle of incline of the ramp until the object(s) begin to slide down. The ramp also has two additional covers which you can use to change its surface. Between the three objects, and three ramp surfaces, you will have nine total combinations to test.

Make Predictions

- Observe the materials of the three objects, the surface of the ramp, and the two additional ramp coverings and make the following predictions:
  - I predict the greatest amount of friction will occur between the_____ (object) and the _____ (ramp surface).
  - I predict the least amount of friction will occur between the_____ (object) and the _____ (ramp surface).

Test

Prepare the table below by filling out the first two columns. In the first column labeled "Ramp Material," place the types of materials the ramp is made of, including the bare ramp material and the two additional covers. In the next column marked "Objects," place each of the names of your three objects next to each of the three types of ramp materials.

Career Corner

Using the force of friction to propel you forward across a surface is known as traction. Space Tire Engineer Heather Oravec is reinventing the wheel to ensure that rovers, both robotic and crewed, get plenty of traction as they roam the surfaces of the Moon, Mars, and celestial bodies not yet explored. Why don't you think standard automobile tires would work on a rover on the Moon or Mars? What types of conditions exist on their surfaces, and how would you account for these conditions in a tire design?

To learn more about Heather's journey to her career at NASA and the work she does, visit: https://www.nasa.gov/stem-content/surprisingly-stem-space-tire-engineer/

Data Table

Ramp Material	Objects	Angle of Ramp (In Degrees)			
		Trial 1	Trial 2	Trial 3	Average

- Begin your experiment by placing your bare ramp, with no additional covering, flat on the floor or on a sturdy table. Then, place one of your small items at one end of the ramp and the protractor vertically at the other end, aligning the zero-degree mark with the end of the ramp.
- Test the static friction between the two surfaces by slowly elevating the end of the ramp with the small item on top. As one group member slowly raises the ramp, another should hold and observe the protractor, keeping track of the degree of angle of the ramp. A third group member should observe the small item as their teammate raises the ramp and alert the other team members the moment when the object begins to slide down the ramp. In the table above, record the angle of the ramp at the point the object begins to slide. Perform three trials of the test and find the average.
- Repeat the test using the other two small objects.
- After performing the test for each of the three small objects on the bare ramp, use tape to cover your ramp with one of the two other materials, giving the ramp a different surface with different friction properties.
- Repeat the tests for all three small objects, recording your results in the table above.
- Finally, cover your ramp with the third material and repeat the tests with each of the three small objects.
- After completing the experiment, answer the following questions:
  - Does an increase in the angle of the ramp before the object begins to slide show greater or lesser static friction? _____
  - Which of the material combinations showed the greatest amount of static friction? _____
    - At what angle did the object begin to slide? _____
  - Which of the material combinations showed the least amount of static friction? _____
    - At what angle did the object begin to slide? _____
  - Were the results the same as you predicted? Explain.

    _____

    _____

    _____

Share

- Prepare to share your group's findings with the rest of the class. Also, read and think about the following questions. Prepare to share your thoughts and ideas as your teacher leads a class discussion.
  - If gravity was pulling your objects down the ramp, in what direction was the friction acting on your objects?
  - As you raised your ramps, static friction held your objects in place until the ramp was at a steep enough angle that static friction could no longer hold them. When the objects began to slide down the ramp, was static friction still affecting them? If not, what kind of friction was affecting them?
  - When the objects began to slide down the ramps, did they slide all the way, or did they stop partway? What does this say about the difference between static friction and kinetic friction? Which of the two frictional forces is stronger?
  - If two identical cars traveling at the same velocity both slam on their brakes quickly, and the wheels of one car locked causing the car to skid, which of the two cars will stop more quickly? Does this scenario help you understand why anti-lock brakes in vehicles help them slow down faster?
  - After performing this experiment, what properties of materials do you think would either increase or decrease their friction?