Friction
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Subject: Physics
Level: Middle School students
   Standard 1- Analysis, Inquiry and Design
   Standard 4- The Physical Setting
   Standard 6- Interconnectedness: Common Themes
   Standard 7- Interdisciplinary Problem Solving
Schedule: Two or three 40-minute class periods

Objectives:
Learn about the properties and types of friction and how it affects students' lives.

Students will:
- Conduct a variety of experiments to understand the amount of friction between two surfaces
- Observe some by-products and different types of friction
- Observe and calculate how friction balances the force of gravity
- Review and discuss concepts learned

Vocabulary:
<table>
<thead>
<tr>
<th>Friction</th>
<th>Static</th>
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<tr>
<td>Force</td>
<td>Kinetic</td>
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<tr>
<td>Gravity</td>
<td>Drag</td>
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Materials:
For Each Pair:
- Blocks
- Velcro
- Hex Nuts
- Friction Board
  - a. Cardboard
  - b. Rubber
  - c. Sandpaper
  - d. Cork
- Various small weights
- Balloons

For Each Student:
- Activity Sheet 1: What determines the amount of friction between two surfaces?
- Activity Sheet 2: Is Friction the villain or the hero?
- Activity Sheet 3: Some Experiments with Friction
- Activity Sheet 4: Where does all that energy go?

Safety:
This activity does not contain any safety concerns.
Science Content:

Introduction

Friction is a part of our everyday lives. Nearly every movement we make involves friction, and we have instinctively learned to take advantage of friction, or the lack of friction, since our childhood.

Simple devices that rely on friction are everywhere around us. This activity will help you see and appreciate the role of friction. As we study friction, let’s also think about the differences between what scientists do and what engineers do.

Scientists and engineers have been studying friction and its effects for a very long time. Engineers in particular have a real "love-hate" relationship with friction. For many jobs, an engineer must fight against friction and its effects through careful, clever design. In this activity, we'll talk about the wedge and the wheel -- the ancient engineers' tremendously successful approach to friction. Roughly speaking, the scientist's role is to understand friction, what causes it and how those causes can be controlled. The engineer's role is to anticipate friction's part in the task at hand, and to use friction to the best advantage in the design of materials, machines, and experiments.

In this activity, you will be a scientist, doing experiments to learn about friction and thinking about how it works; and then you will be an engineer when you design your own car to win a "slow" race down a ramp. You'll learn that there is no practical way to eliminate friction. Like the tortoise in the famous story, friction always "wins," eating away at energy you put into motion, slow and steady. Sooner or later, friction will cause the motion to stop. Ultimately, friction wins!

What is friction?

Friction is the force that opposes sliding motion. It is the resistance to the movement of one body in relation to another body with which it is in contact. For example, if we try to slide a wooden block across a table, then friction acts in the direction opposite to the movement of the block.

Identifying the forces involved in friction

Let's talk about forces. Forces are pushes or pulls. Understanding forces is very important to many physicists and engineers. Researchers have spent a great deal of time defining a "language" of forces. We'll define some of the language of forces in this activity.
Forces act in a certain direction. Think about gravity. What direction does gravity always act in? _______. If something is not moving, all the forces on it are balanced: not only the amount of force, but also the direction. Did you say that gravity acts down? Good. Now, if there is a book on a table, and gravity is pulling down on the book, what sort of force is the table exerting on it?

The table pushes up with exactly the same force that gravity pushes down. That force is equal to the weight of the book.

Now, suppose that the table is at an angle, like an engineer's drawing board. Gravity still pushes down, but the table is not pushing straight up. It is pushing at an angle perpendicular to the table surface. Another force is needed to keep the book from sliding down the table: that's friction!

What direction does friction push in, and how strong is the force of friction? These are not easy questions! Let's think about some differences between friction and gravity on earth:

**Gravity** always pushes (or pulls) down.

**Friction** always pushes (or pulls) in the direction opposite to the direction that the object is sliding, or would slide if there were no friction.
Friction always acts parallel to the surfaces in contact, because that is where sliding happens.

Gravity always has a force equal to the weight of the object that it is acting on, and the object's weight is directly related to its mass.

Friction on a static object (no sliding) has a force exactly large enough to resist sliding, up to a certain maximum -- if the force trying to slide is larger than this maximum, then the object slides. We'll do some experiments later to see what this maximum force depends on.

Friction on a sliding object depends on the same things that determine the maximum for static friction, and is always a little bit less than that maximum.

Does this seem complicated? Don't worry. We'll do some experiments to understand friction. After all, we use it every day and hardly even think about it!

**Preparation:**

1. Photocopy print materials (*Activity Sheets 1-3*) for each student pair.
2. Prepare materials to be easily accessible to students.
**Classroom Procedure:**

*Engage (Time: 15 mins)*

Use Velcro to create an analogy to help understand friction. Ask students if they’ve ever looked at Velcro up close to see how it works. One side contains many small loops, and the other side contains many small hooks. The hook side not only connects to the loop side, but will also attach itself to some other fabrics. It connects more strongly to some fabrics than others. Explain that this is what friction is like, but on an atomic level. Rather than loops and hooks, there are peaks and valleys that catch each other to prevent movement. Different surfaces have different irregularities, so just like different fabrics attach to Velcro with different strengths, different surfaces have different frictional resistances to sliding.

Have students make fists and put their knuckles together, then try to slide their hands across each other. Explain that their difficulty in moving their hands is the same as on the atomic level when surfaces are pressed together. This simple experiment can show three facts about friction:

1) You can see how irregularities prevent motion.
2) You can see that the harder your hands are pressed together, the harder it is to slide them. Higher perpendicular forces create more friction.
3) If you bring your fists together while they are moving sideways, it will be easier to keep them sliding. The friction between static surfaces is greater than the friction between moving surfaces.

Review static and kinetic friction as well as other concepts outlined in the ‘Science Content’ section. Ask students to think of examples where friction is important to their own lives.

*Explore (Time: 25 mins)*

Distribute materials and Activity Sheets to the students. Have students work through Activity Sheets 1-5 either individually or with partners. Assist as necessary.
Day 2

Explore (Time: 40 mins)

Allow students to finish working through Activity Sheets 1-5, assist and answer questions as necessary.

Day 3

Explore (Time: 25 mins)

Now that the students understand more about friction, pass out the Styrofoam blocks. Tell students that they will now design a tortoise for the race. The race will consist of a long board propped at about 45°. They can attach any of the materials to the Styrofoam block and then decorate it. The aim of the race is to be the slowest tortoise to reach the bottom. Only two tortoises will race at a time, the slowest one remaining to race again. For a tortoise to be considered the winner, it must not only be slower, but it must also reach the bottom (no stalled tortoises!). Let the race begin!

Explain (Time: 15 mins)

As a class, have students present and discuss their findings on friction. What increases or decreases friction? What types are there? Where does the energy go that was used to overcome friction? Also discuss answers to the vector problem presented in Activity Sheet 5. Additionally, Activity Sheet 6 can be used to pose questions or as homework. Also have students present their finding with the tortoises: what made the best tortoises? What could be changed or improved?
Assessment:

The following rubric can be used to assess students during each part of the activity. The term “expectations” here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

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<thead>
<tr>
<th>Engage</th>
<th>Explore</th>
<th>Explain</th>
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<tbody>
<tr>
<td>1</td>
<td>Shows leadership in the discussion and offers creative ideas reflecting a good understanding of friction.</td>
<td>Completes work accurately while providing an explanation for what is observed.</td>
</tr>
<tr>
<td>2</td>
<td>Participates in the discussion and shows an understanding of friction.</td>
<td>Completes work accurately.</td>
</tr>
<tr>
<td>3</td>
<td>Contributes to the discussion, but shows little understanding of friction.</td>
<td>Makes some mistakes with the procedure.</td>
</tr>
<tr>
<td>4</td>
<td>Does not participate in activity. Shows no understanding of friction.</td>
<td>Does little to complete the procedure.</td>
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Extension Activities:

- Friction: Understanding your Tortoise

  1. If you could redesign your tortoise now, how would you make it travel down the ramp more slowly? *(A reminder: Friction is caused by the peaks and valleys of the two surfaces).
  2. Do you think that two pieces of wood rubbing together would have more or less friction than wood rubbing against smooth metal? Why?
  3. Why do you think that oil is spread on metal parts that rub against each other (like in a car engine)? Friction: Good or Bad?
  4. Is friction good or bad for walking? *(Hint: Is it harder to walk on an icy path?)
  5. Friction with the air slows down a race car. How is a race car shaped to reduce air friction?

- If you would like the students to learn more about how friction balances the force of gravity, refer to Activity Sheet 5.

Supplemental Information:

- Other types of friction

  I. Friction between a solid surface and a liquid or gas

  We have mostly been discussing two solid surfaces and the friction between them. Remember that friction increases as we press the two surfaces together. Now what about a solid object being pushed through air or water? This type of friction has a special name: drag. It is pretty complicated, and scientists have studied it for many years. Drag depends on the shape of the moving solid and its speed. Here’s an experiment to look at drag:

  Take two balloons an inflate one. Hold them out. Which way is gravity acting on the balloons? If you drop them, which way will drag be acting? Drop them. Which one lands first? Why?
You can try a similar experiment dropping clay in water, timing the drops.

If you do this experiment, you might wonder if gravity is acting differently on the different objects you drop. Galileo, a famous Italian scientist, did an experiment that proved that, if you only consider gravity, all things on earth fall at the same speed. So, the only thing that can change how fast your objects are falling is friction. If you don’t believe this, repeat Galileo’s experiment: you will need to drop two objects that have the same friction, but different weights. If your friction comes from drag, then that means that they should be the same size and shape. Can you think of a way to do this?

II. Granular materials

Little particles of material also interact with each other and have friction. This is called internal friction. What would happen if you poured a cup of water on the table? Do you think that water molecules slide over each other easily? What if you poured sand on the table? It piles up, and the pile is held together by internal friction, so you can say that sand has a high internal friction.

Next time you help your father or mother cook, pay attention to the internal friction of the ingredients you use: flour, sugar, rice, salt, parmesan cheese, and so on. Which powders have low internal friction? Which ones have high internal friction? Are there any with so much friction that they keep the shape of the measuring cup after you dump them? Have you ever started to pour salt into a measuring spoon and then not been able to stop in time? Static and kinetic friction can also be found when we are talking about internal friction!

Internal friction is important for construction engineers. They test concrete by measuring internal friction: it’s called slump, then. Have you looked at any of the local gorges this spring? You can probably see spots where the winter weather has washed away the soil and spots where dirt and small rocks still cover the steep slopes. What does this have to do with friction?

If you were a construction engineer, would you care about the internal friction of the soil where you were building a house?
Here’s something else to think about, when you work as a construction engineer this summer. When we build a sandcastle, we use damp sand to do it, because if we used dry sand, the internal friction would be too low and the sandcastle would crumble. But we just learned that adding a fluid is a way to reduce friction! What is going on here?

1. Water is a poor lubricant. Its molecules tend to “stick” to surfaces like sand. This is one reason why people often use oils and greases, even though water is so abundant. (Another reason is that water would rust metal machine parts.)

2. Friction and drag often behave differently when in very small spaces, like the distance between two grains of sand, than in large spaces like sliding blocks or a boat sliding in water. In small spaces, the chemical “stickiness” of the molecules becomes much more important and can actually increase friction.

As you can see, friction is very basic but also a very exciting topic that scientists are always learning new things about!

**Safety:**

- This activity does not contain any safety concerns.