4.1

KEY CONCEPT

Work is the use of force to move an object.

BEFORE, you learned

- An unbalanced force produces acceleration
- Weight is measured in newtons

NOW, you will learn

- How force and work are related
- How moving objects do work

VOCABULARY

work p. 115
joule p. 117

EXPLORE Work

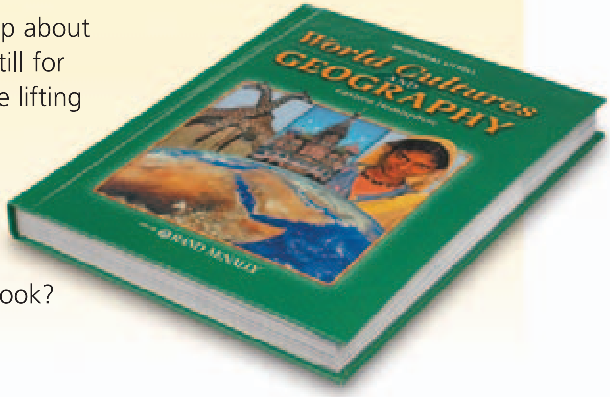
How do you work?

PROCEDURE

1. Lift a book from the floor to your desktop. Try to move the book at a constant speed.
2. Now lift the book again, but stop about halfway up and hold the book still for about 30 seconds. Then continue lifting the book to the desktop.

MATERIALS

book



WHAT DO YOU THINK?

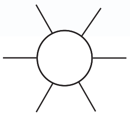
- Do you think you did more work the first time you lifted the book or the second time you lifted the book?
- What do you think *work* means?

Force is necessary to do work.

What comes to mind when you think of work? Most people say they are working when they do anything that requires a physical or mental effort. But in physical science, **work** is the use of force to move an object some distance. In scientific terms, you do work only when you exert a force on an object and move it. According to this definition of work, reading this page is not doing work. Turning the page, however, would be work because you are lifting the page.

Solving a math problem in your head is not doing work. Writing the answer is work because you are moving the pencil across the paper. If you want to do work, you have to use force to move something.

VOCABULARY
You might want to make a description wheel diagram in your notebook for *work*.



CHECK YOUR READING How does the scientific definition of work differ from the familiar definition?

RESOURCE CENTER
CLASSZONE.COM
Learn more about work.

Force, Motion, and Work

Work is done only when an object that is being pushed or pulled actually moves. If you lift a book, you exert a force and do work. What if you simply hold the book out in front of you? No matter how tired your muscles may become from holding the book still, you are not doing work unless you move the book.

The work done by a force is related to the size of the force and the distance over which the force is applied. How much work does it take to push a grocery cart down an aisle? The answer depends on how hard you push the cart and the length of the aisle. If you use the same amount of force, you do more work pushing a cart down a long aisle than a short aisle.

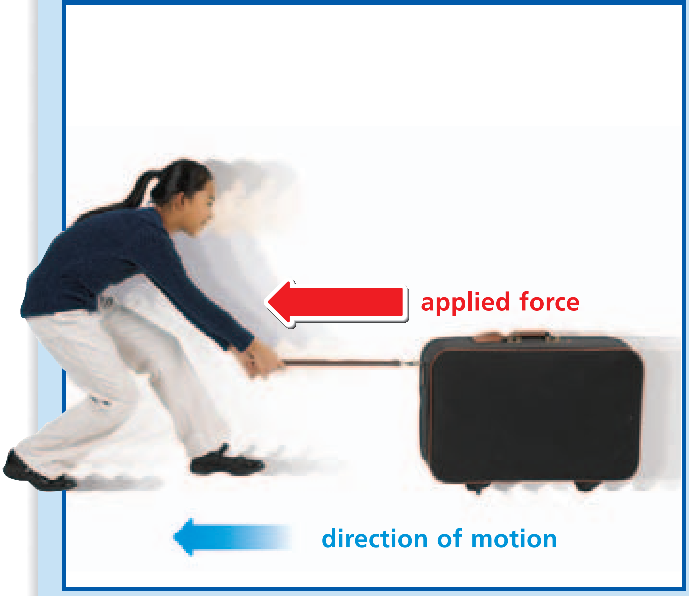
Work is done only by the part of the applied force that acts in the same direction as the motion of an object. Suppose you need to pull a heavy suitcase on wheels. You pull the handle up at an angle as you pull the suitcase forward. Only the part of the force pulling the suitcase forward is doing work. The force with which you pull upward on the handle is not doing work because the suitcase is not moving upward—unless you are going uphill.

CHECK YOUR READING Give two examples of when you are applying a force but not doing work.

Work

Work is done by force that acts in the same direction as the motion of an object.

All of the Applied Force Does Work



Part of the Applied Force Does Work

READING VISUALS How does changing the direction of the applied force change the amount of the force that is doing work?

Calculating Work

Work is a measure of how much force is applied over a certain distance. You can calculate the work a force does if you know the size of the force applied to an object and the distance over which the force acts. The distance involved is the distance the object moved in the direction of that force. The calculation for work is shown in the following formula:

$$\text{Work} = \text{Force} \cdot \text{distance}$$
$$W = Fd$$

This man is doing work when he applies force to lift his body.

You read in previous chapters that you can measure force in newtons. You also know that you can measure distance in meters. When you multiply a force in newtons times a distance in meters, the product is a measurement called the newton-meter (N•m), or the **joule** (jool).

The joule (J) is the standard unit used to measure work. One joule of work is done when a force of one newton moves an object one meter. To get an idea of how much a joule of work is, lift an apple (which weighs about one newton) from your foot to your waist (about one meter).

Use the formula for work to solve the problem below.

Calculating Work

Sample Problem

How much work is done if a person lifts a barbell weighing 450 N to a height of 2 m?

What do you know? force needed to lift = 450 N, distance = 2 m

What do you want to find out? Work

Write the formula: $W = Fd$

Substitute into the formula: $W = 450\text{ N} \cdot 2\text{ m}$

Calculate and simplify: $W = 900$ N•m

Check that your units agree: Unit is newton-meter (N•m).
Unit of work is joule, which is N•m.
Units agree.

Answer: $W = 900$ J

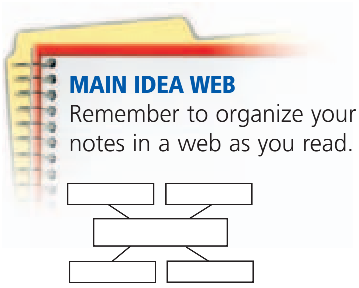
Practice the Math

1. If you push a cart with a force of 70 N for 2 m, how much work is done?
2. If you did 200 J of work pushing a box with a force of 40 N, how far did you push the box?

REMINDER

You know that $W = Fd$. You can manipulate the formula to find force or distance.

$d = \frac{W}{F}$ and $F = \frac{W}{d}$



MAIN IDEA WEB
Remember to organize your notes in a web as you read.

Objects that are moving can do work.

You do work when you pick up your books, hit a baseball, swim a lap, or tap a keyboard. These examples show that you do work on objects, but objects can also do work.

For example, in a bowling alley, the bowling balls do work on the pins they hit. Outdoors, the moving air particles in a gust of wind do work that lifts a leaf off the ground. Moving water, such as the water in a river, also does work. If the windblown leaf lands in the water, it might be carried downstream by the current. As the leaf travels downstream, it might go over the edge of a waterfall. In that case, the gravitational force of Earth would pull the leaf and water down.

You can say that an object or person does work on an object, or that the force the object or person is exerting does work. For example, you could say that Earth (an object) does work on the falling water, or that gravity (a force) does work on the water.

INVESTIGATE Work

How much work does it take?

SKILL FOCUS
Measuring

MATERIALS
- meter stick
- spiral notebook
- spring scale

TIME
20 minutes

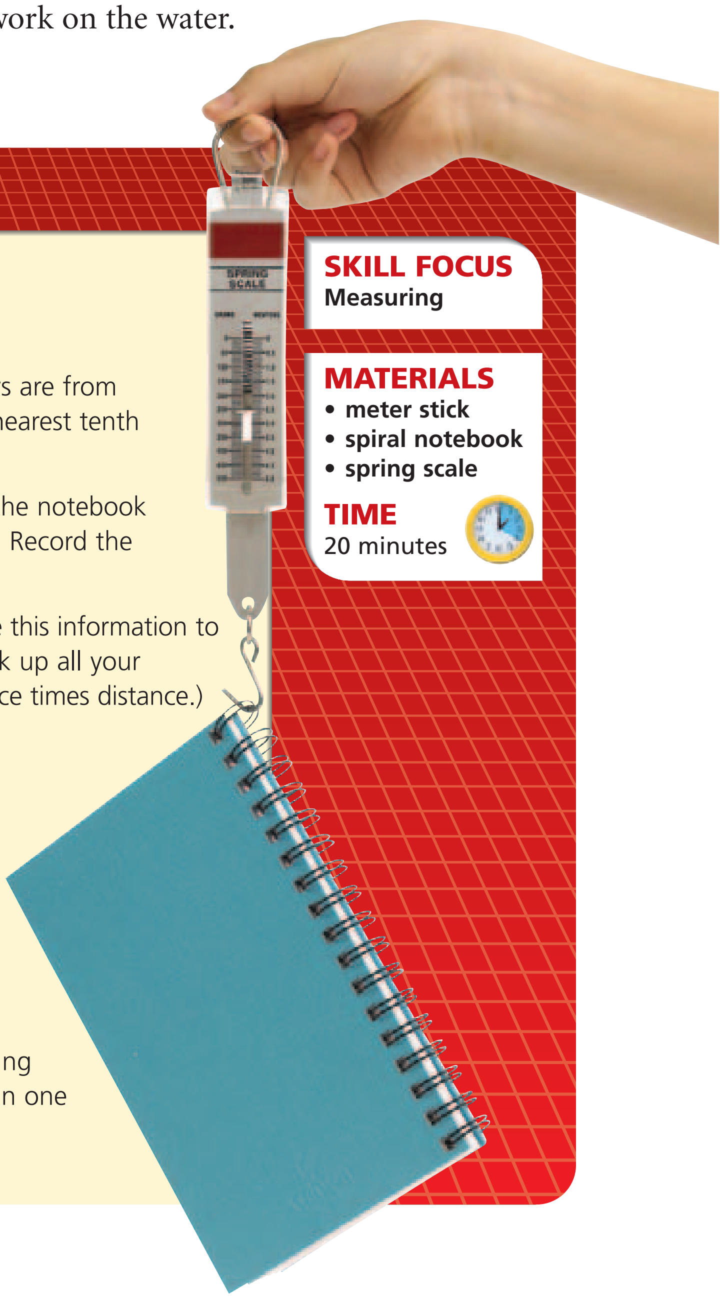
PROCEDURE

1. Have a partner help you measure how high your shoulders are from the ground. Record the distance in meters. Round to the nearest tenth of a meter.
2. Attach the notebook to the spring scale. Then slowly lift the notebook to your shoulder to see how much force you are exerting. Record the amount in newtons.
3. Calculate the work you did while lifting one notebook. Use this information to estimate how much work you do every day when you pick up all your notebooks to take them to school. (**Hint:** Work equals force times distance.)

WHAT DO YOU THINK?

- Approximately how much work does it take to pick up your notebook?
- How would the amount of work you do change if you were shorter? taller?
- How much work are you doing on the notebook if you have stopped to talk to a friend?

CHALLENGE If you pick up a notebook 10 times a day during the school year, how much work do you do on the notebook in one year? (Assume that there are 180 school days in a year.)



APPLY How could you increase the work done by this water wheel?

Throughout history, people have taken advantage of the capability of objects in motion to do work. Many early cultures built machines such as water wheels to use the force exerted by falling water, and windmills to use the force exerted by moving air. In a water wheel like the one in the photograph, gravity does work on the water. As the water falls, it also can do work on any object that is put in its path. Falling water can turn a water wheel or the turbine of an electric generator.

The water wheel shown above uses the work done by water to turn gears that run a mill and grind grain. In the same way, windmills take advantage of the force of moving air particles. The wind causes the sails of a windmill to turn. The turning sails do work to run machinery or an irrigation system.

CHECK YOUR READING Describe how a water wheel does work.

4.1 Review

KEY CONCEPTS

1. If you push very hard on an object but it does not move, have you done work? Explain.
2. What two factors do you need to know to calculate how much work was done in any situation?
3. Was work done on a book that fell from a desk to the floor? If so, what force was involved?

CRITICAL THINKING

4. **Synthesize** Work is done on a ball when a soccer player kicks it. Is the player still doing work on the ball as it rolls across the ground? Explain.
5. **Calculate** Tina lifted a box 0.5 m. The box weighed 25 N. How much work did Tina do on the box?

CHALLENGE

6. **Analyze** Ben and Andy each pushed an empty grocery cart. Ben used twice the force, but they both did the same amount of work. Explain.