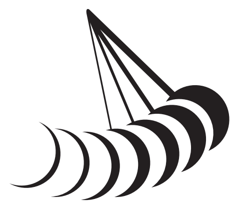
Hands-On Science



Force & Motion

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illustrated by Lloyd Birmingham

WALCH EDUCATION®

Contents

Name ______________________ Date ______________

8. Friction

STUDENT ACTIVITY PAGE

2. In step 7, what does the addition of 20 pennies to the margarine tub do to the magnitude of the normal force between the tub and the table surface? What does this do to the force of friction? What must you do to the film canister to get the tub to move?

3. From your results in the bold-outlined boxes in the Data Table, which surface produces the most friction? Which produces the least?

4. Some of the error in this activity comes from a source of friction other than that between the bottom of the margarine tub and the surface it sits on. Find and describe this source of friction, and suggest a way to reduce it.

FOLLOW-UP ACTIVITIES

1. This activity measures static friction. Think up and describe an experiment to measure the force of kinetic friction, the friction between two moving objects, using just a spring scale, a flat surface, and an object of known weight. If you have access to these materials, try the experiment!
2. List as many parts of a car as you can that are intended to reduce friction. List those that use friction in order to work. Look carefully and think about the function of each part—you might find some surprises.

9. Work (the Physics Kind)

TEACHER RESOURCE PAGE

Instructional Objectives

Students will be able to:

- describe the physical concept of work
- demonstrate work

National Science Education Standards Correlations

Grades 5–8

Content standard	Bullet number	Content description	Bullet number(s)
A	1	Abilities necessary to do scientific inquiry	1–7
A	2	Understandings about scientific inquiry	1–5
B	3	Transfer of energy	1
E	1	Abilities of technological design	3

Grades 9–12

Content standard	Bullet number	Content description	Bullet number(s)
A	1	Abilities necessary to do scientific inquiry	1–4
A	2	Understandings about scientific inquiry	3–5
B	4	Motions and forces	1
B	5	Conservation of energy and increase in disorder	2
E	1	Abilities of technological design	3–5

Vocabulary

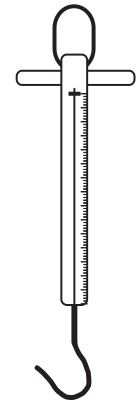
- **friction:** a force that opposes the motion of two objects that are in contact and are moving past each other
- **negative work:** force that is applied opposite to the direction of motion of a moving object
- **positive work:** force that is applied in the direction of motion of a moving object
- **work:** force applied to an object times the distance the object moves in the direction of the applied force

9. Work (the Physics Kind)

MATERIALS

For each pair:

- spring scale (range 4 to 10 pounds preferred)
- smooth floor
- a supply of books, either hardcover or softcover
- cardboard box large enough to fit about 10 books
- meterstick or tape measure
- masking tape
- string



HELPFUL HINTS AND DISCUSSION

Time frame: 40 to 50 minutes, or one class period
Structure: pairs
Location: classroom

Try this exercise with materials on hand before giving them to students. If no floor or table works well, try using a sheet of plywood or paneling to provide a more uniform surface. Remind students to pull horizontally in step 4, making sure that they do not cause the front edge of the box to rise as they pull. Encourage them to practice pulling on the scale with uniform force before they proceed to step 5. When a student pulls the box with the spring scale, the reading on the scale may briefly go high until the box breaks free of the static friction; then it will settle down to a constant reading as the student pulls slowly and uniformly. Students should ignore the initial high-force reading and record the force during steady motion. This activity should ordinarily be assigned after Activity 8: Friction. Students in a group may collect common data, but each should do his or her own calculations and Concluding Questions.

MEETING THE NEEDS OF DIVERSE LEARNERS

Encourage students who need extra challenges to do the Extension Option and the Follow-Up Activity. You can also guide them to texts with a more mathematical treatment of the subject.

For students who need extra help, review the relevant concepts, such as force, weight, and friction. These students can be paired with advanced students for the activity.

SCORING RUBRIC

Students meet the standard for this activity by:

- correctly describing the physical concept of work
- demonstrating the relationship among work, force, and distance
- correctly using equipment
- reaching conclusions based on collected data

9. Work (the Physics Kind)

TEACHER RESOURCE PAGE

RECOMMENDED INTERNET SITES

- **Bartleby.com—Work**
  www.bartleby.com/65/wo/work.html
- **Georgia State University HyperPhysics—Mechanics: Work, Energy and Power**
  http://hyperphysics.phy-astr.gsu.edu/Hbase/work.html#wep
- **The Physics Classroom Tutorial—Lesson 1: Basic Terminology and Concepts**
  www.glenbrook.k12.il.us/gbssci/Phys/Class/energy/u5l1a.html

ANSWER KEY

1. Work increases as you increase the distance the box is dragged.
2. Adding books increases the friction and requires more force to move the box at a constant speed.
3. Work increases as you increase the force required to drag the cardboard box.
4. The amount of work done should not change a great amount. The speed that work is done does not significantly change the amount of work done. It does, however, increase the amount of power utilized.

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9. Work (the Physics Kind)

Student Activity Page

Objective

To describe and demonstrate the physical concept of work

Before You Begin

When you hear the word *work,* a wide range of activities might come to mind. You might imagine taking out the trash, studying for a history exam, or mowing the lawn. In physics, however, "work" has a very specific meaning. Think about pulling a bowl of pasta across the dinner table toward you. You exert a force on the bowl to counteract the force of **friction** that resists the bowl's sliding. As a result, the bowl moves a certain distance. **Work** (W) is defined as the magnitude of the force (F) exerted on an object, multiplied by the distance (d) traveled by the object in the same direction as the force while the force is acting.

$$W = F \cdot d$$

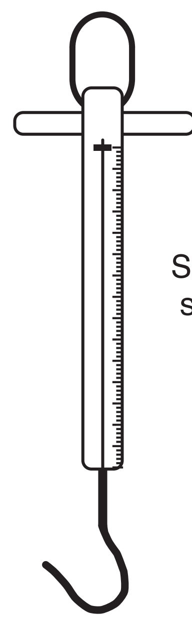
The amount of work done will increase if the magnitude of the force is increased, if the force acts on the object over a greater distance, or both. Notice that work is a scalar quantity, even though force is a vector.

Work can be either positive or negative. If you push a car on level ground and it rolls away from you, the force you exert does **positive work** on it. If the car is rolling downhill toward you and you try to hold it back, you might exert exactly the same force on the car. However, since the direction of motion is opposite the direction of the force, the work done by you on the car is **negative work.** In this case, the car does work on you! Work is done only if something is moved to a different location than its starting point. You might push with all your might against a building and quickly become exhausted, but unless the building moves, no work has been done on it!

Materials

For each pair:

- spring scale (range 4 to 10 pounds preferred)
- smooth floor
- a supply of books, either hardcover or softcover
- cardboard box large enough to fit about 10 books
- meterstick or tape measure
- masking tape
- string



Spring scale

Procedure

1. Place the cardboard box on the floor. Put 3 to 5 books into the box.
2. Hook the spring scale to the box. You might need to punch a hole in the box to attach the end of the hook.

9. Work (the Physics Kind)

3. Place a small piece of masking tape on the floor at the front edge of the box to indicate the box's starting position.
4. One team member will pull the box, while the other will watch the spring scale to make sure the measurement is not too high or low. Read the following instructions according to your task before you start.

   If you are pulling the box:

   - Hold on to the end of the spring scale that is not attached to the box.
   - As you drag the box, move it slowly and keep a constant force.
   - Keep the scale parallel to the floor as you drag the box.
   - Do not allow the spring scale to lift the box.

   If you are reading the scale:

   - Watch the scale as your partner drags the box.
   - Read the force on the scale only while the box is moving at constant speed, not when starting up or coming to a stop. Practice until you feel comfortable doing this.
   - Make sure that the scale reads a constant force (weight) in the low half of the scale's range.
   - If the scale reads too high (too much force), take out books one at a time as needed.
   - If the scale reads too low (little or no force), add books.
   - Record the force in the Data Collection and Analysis section.
   - After your partner has finished dragging the box, measure the distance it traveled.
   - Record this value in the Data Collection and Analysis section.
5. Drag the box in a straight line slowly across the floor, for a distance of about 1 meter.
6. Record the force and distance as "Trial 1" in the Data Collection and Analysis section.
7. Switch jobs with your partner. Read over the steps for each job before you proceed.
8. Mark the box's new starting point with a piece of tape.
9. Drag the box again, but this time move the box several times as far as before. Try to use the same force as before.
10. Measure and record the force and the distance the box traveled as "Trial 2" in the Data Collection and Analysis section.
11. Add 3 to 5 books to the cardboard box.
12. Mark the box's new starting position with tape.
13. Drag the box 1 meter. Follow the same procedures as before when dragging the box and making observations.
14. Measure and record the force you exerted and the distance the box traveled as "Trial 3" in the Data Collection and Analysis section.

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9. Work (the Physics Kind)

STUDENT ACTIVITY PAGE

EXTENSION OPTION

Repeat step 13, this time moving the box the same distance but about twice as fast. Measure and record the force and the distance the box traveled in the space provided.

DATA COLLECTION AND ANALYSIS

If your scale reads in pounds, convert to newtons (1 pound = 4.45 N).

If your tape measure reads in inches, convert to meters (1 m = 39.4 inches).

In each line below, use your measured values for force and distance to calculate the work you did in dragging the box.

Trial 1	force = _______ N	distance = _________ meters	work = _________ N-m
Trial 2	force = _______ N	distance = _________ meters	work = _________ N-m
Trial 3	force = _______ N	distance = _________ meters	work = _________ N-m

Extension Option

Trial 4	force = _______ N	distance = _________ meters	work = _________ N-m

CONCLUDING QUESTIONS

1. Does the work done increase or decrease when you increase the distance you drag the cardboard box?

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2. Why does adding books to the box change the results?

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Name ______________________ Date ______________________

9. Work (the Physics Kind)

STUDENT ACTIVITY PAGE

3. Does the work done increase or decrease when the force required to drag the cardboard box is increased?

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Extension Option

4. For the Extension, you moved the box at about twice the speed you used in step 13. Did the work done by you on the box also double? Does "work" (as it applies to physics) depend significantly on how fast an object is moved?

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FOLLOW-UP ACTIVITY

Borrow a spring scale and bring it home. Make a list of at least five ordinary tasks that you think involve work of the physics kind (like putting a stack of clean dishes away in the cabinet). Using either the spring scale or a bathroom scale, and a tape measure or ruler to measure distance, estimate the work done in newton-meters to do that task. Once this is done, put your list of tasks in order from the greatest to least amount of work. (**Keep the tasks simple and safe.** Carrying an unopened gallon of paint up a flight of stairs is okay, but rebuilding an automobile transmission is not. Also, note that if you slowly lift an object, the upward force you exert on it is approximately equal to its weight.)