Chapter 19

# Work and Machines

## Standard Course of Study

**1.01** Identify and create questions and hypotheses.

**1.02** Develop appropriate experimental procedures.

**1.03** Apply safety procedures.

**1.04** Analyze variables.

**1.05** Analyze evidence.

**1.06** Use mathematics to gather, organize, and present data.

**1.07** Prepare models and/or computer simulations.

**1.08** Use oral and written language.

**1.09** Use technologies and information systems.

**2.01** Explore definitions of "technology."

**2.02** Use information systems.

**2.03** Evaluate technological designs.

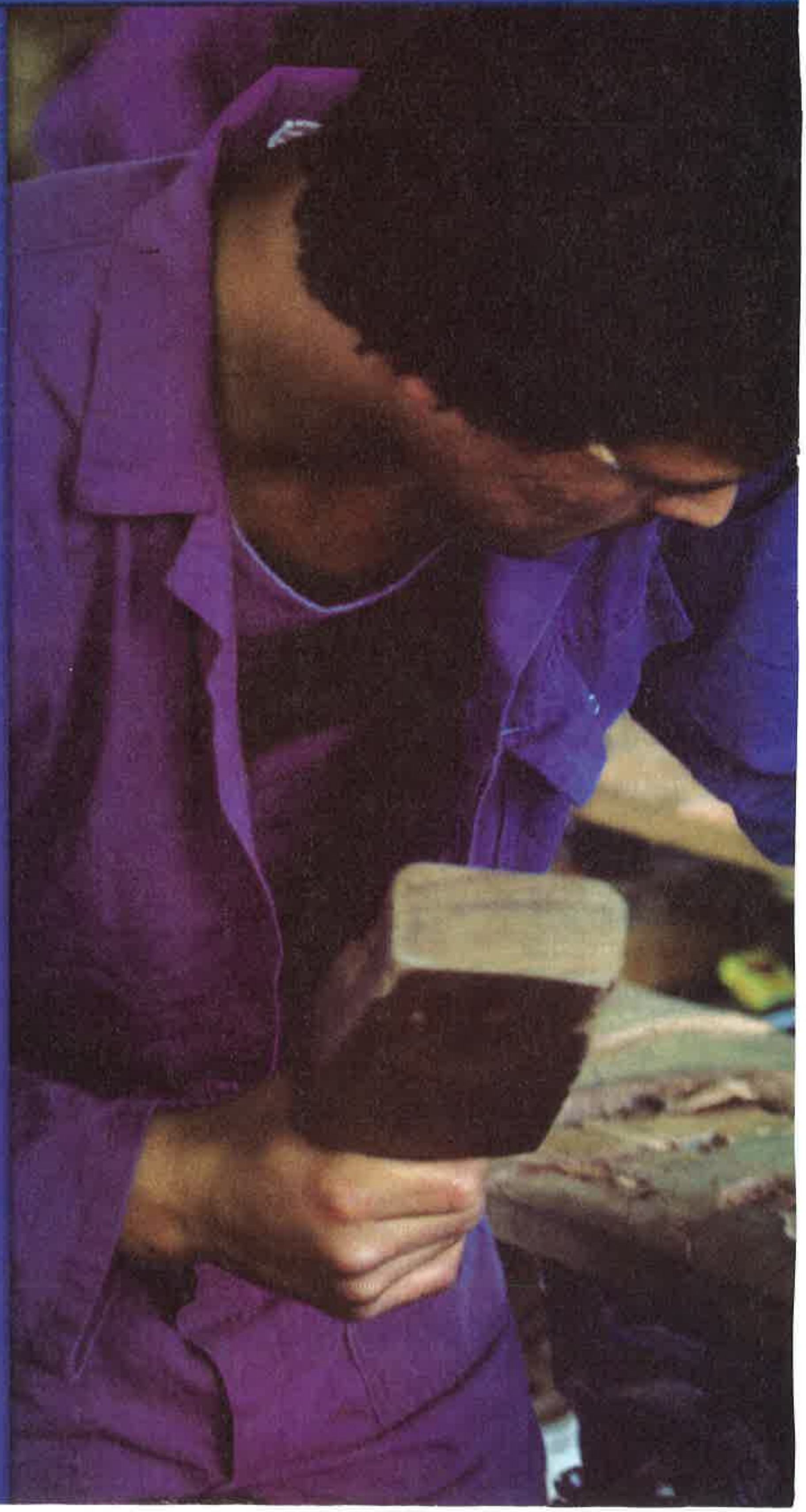
**6.01** Demonstrate how simple machines change force.

**6.02** Analyze simple machines for mechanical advantage and efficiency.

**6.05** Describe and measure quantities that characterize moving objects and their interactions.

**6.06** Investigate and analyze real-world interactions of balanced and unbalanced forces.

Interactive Textbook



A Maori woodcarver in New Zealand creates a traditional carving.

# End-of-Grade Test Practice

### Test-Taking Tip

**Anticipating the Answer**

You can sometimes figure out an answer before you look at the answer choices. After you provide your own answer, compare it with the answer choices. Select the answer that most closely matches your own answer. This strategy can be especially useful for questions that test vocabulary. Try to answer the question below before you look at the answer choices.

***Sample Question***

Any material that can easily flow is considered a

**A** liquid.
**B** fluid.
**C** gas.
**D** metal.

***Answer***

Gases and liquids can easily flow. However, they are both fluids. The definition of a fluid is "a material that can easily flow." The correct answer is **B.**

**Choose the letter of the best answer.**

**1.** The upward force that acts on an airplane's wing is called
**A** density.
**B** inertia.
**C** lift.
**D** pressure.

**2.** Which of the following is an example of a hydraulic system?
**A** a car's brakes
**B** a barometer
**C** an airplane's wing
**D** a submarine's flotation tanks

**3.** A boat that weighs 28,800 N is loaded with 7,200 N of cargo. After it is loaded, what is the buoyant force acting on the boat?
**A** 400 N
**B** 22,000 N
**C** 36,000 N
**D** 360,000 N

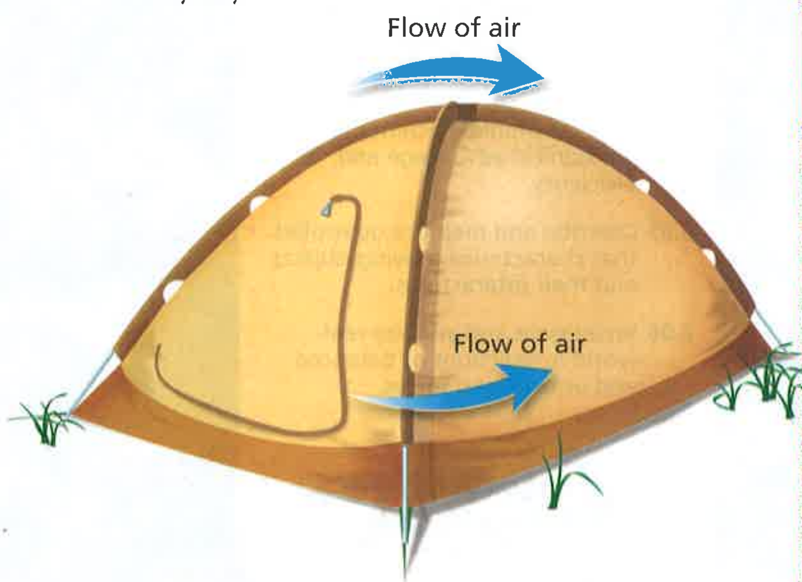
**4.** Why doesn't air pressure crush human beings standing at sea level?
**A** Air pressure at sea level is very low.
**B** Clothing on our bodies shields us from air pressure.
**C** Air is not as heavy as human beings.
**D** Pressure from the fluids inside our bodies balances the air pressure outside.

**5.** You observe that a chunk of tar sinks in puddles of rainwater but floats on the ocean. An experiment to explain the behavior of the tar should measure
**A** the difference between atmospheric pressure and water pressure.
**B** the densities of fresh water, salt water, and tar.
**C** the height from which the chunk of tar is dropped.
**D** the depth of each type of water.

### Constructed Response

*Use the diagram below and your knowledge of science to help you answer Question 6.*

**6.** Use Bernoulli's principle to explain why the fabric of a domed tent bulges outward on a windy day.



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Work and Machines

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Lab zone™ Chapter **Project**

## The Nifty Lifting Machine

In this Chapter Project, you will design and build a lifting machine and then demonstrate it to the class.

**Your Goal** To design, build, and test a complex machine that can lift a 600-gram soup can 5 centimeters

Your machine must

- be made of materials that are approved by your teacher
- consist of at least two simple machines working in combination
- be able to lift the soup can to a height of at least 5 centimeters
- be built following the safety guidelines in Appendix A

**Plan It!** Preview the chapter to find out what simple machines you can use and how to use them. Determine the amount of work your machine must do. Brainstorm different machine designs and materials with your classmates. Analyze factors affecting efficiency and mechanical advantage, and then construct your machine. When your teacher has approved your design, build and test your machine.

Section 1

# What Is Work?

## Reading Preview

### Key Concepts

- When is work done on an object?
- How do you determine the work done on an object?
- What is power?

### Key Terms

- work • joule • power

### Target Reading Skill

**Asking Questions** Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

| Question | Answer |
|---|---|
| What is work? | Work is . . . |
| | |

## Lab zone Discover Activity

### What Happens When You Pull at an Angle?

1. Fill a mug half full with water.
2. Cut a medium-weight rubber band to make a strand of elastic. Thread the elastic through a mug handle. By pulling on the elastic, you can move the mug across a table.
3. You can hold the two halves of elastic parallel to each other or at an angle to each other, as shown. Predict which way will be more effective in moving the mug.
4. Pull on the elastic both ways. Describe any differences you observe.

**Think It Over**

**Developing Hypotheses** Which of the two pulls was more effective in moving the mug? Explain why.

This morning you probably woke up and went to school with your backpack of books. You lifted the backpack and then carried it with you. If you had a lot of books to bring home, carrying your backpack might have felt like a lot of work. But in the scientific definition of work, after you lifted the backpack, you did no work to carry it at all!

## The Meaning of Work

In scientific terms, you do **work** when you exert a force on an object that causes the object to move some distance. **Work is done on an object when the object moves in the same direction in which the force is exerted.** If you push a child on a swing, for example, you are doing work on the child. If you pull your books out of your backpack, you do work on the books. If you lift a bag of groceries out of a shopping cart, you do work on the bag of groceries.


**FIGURE 1**
**Doing Work**
Lifting books out of a backpack is work, but carrying them to class is not.

**No Work Without Motion** To do work on an object, the object must move some distance as a result of your force. If the object does not move, no work is done, no matter how much force is exerted.

There are many situations in which you exert a force but don't do any work. Suppose, for example, you are pushing a car that is stuck in the snow. You certainly exert a force on the car, so it might seem as if you do work. But if the force you exert does not make the car move, you are not doing any work on it.

**Force in the Same Direction** So why didn't you do any work when you carried your books to school? To do work on an object, the force you exert must be in the same direction as the object's motion. When you carry an object at constant velocity, you exert an upward force to hold the object so that it doesn't fall to the ground. The motion of the object, however, is in the horizontal direction. Since the force is vertical and the motion is horizontal, you don't do any work on the object as you carry it.

How much work do you do when you pull a suitcase with wheels? When you pull a suitcase, you pull on the handle at an angle to the ground. As you can see in Figure 2, your force has both a horizontal part and a vertical part. When you pull this way, only part of your force does work—the part in the same direction as the motion of the suitcase. The rest of your force does not help pull the suitcase forward.

**Reading Checkpoint** **If you pull an object horizontally, what part of your force does work?**

**FIGURE 2**
**Force, Motion, and Work**
Whether the girl does work on the suitcase depends on the direction of her force and the suitcase's motion. **Drawing Conclusions** *Why doesn't the girl do work when she carries her suitcase rather than pulling it?*


**A** The lifting force is not in the direction of the suitcase's motion, so no work is done.

**B** The force acts in the same direction as the suitcase's motion, so the maximum work is done.

**C** Only the horizontal part of the force does work to move the suitcase.

**FIGURE 3**
**Amount of Work**
When you lift a plant, you do work. You do more work when you lift a heavier plant the same distance.
**Relating Cause and Effect**
*Why does it take more work to lift the heavier plant?*

## Calculating Work

Which do you think involves more work: lifting a 50-newton potted plant 0.5 meters off the ground onto a table, or lifting a 100-newton plant onto the same table? Your common sense may suggest that lifting a heavier object requires more work than lifting a lighter object. This is true. Is it more work to lift a plant onto a table or up to the top story of a building? As you might guess, moving an object a greater distance requires more work than moving the same object a shorter distance.

The amount of work you do depends on both the amount of force you exert and the distance the object moves. **The amount of work done on an object can be determined by multiplying force times distance.**

$$\text{Work} = \text{Force} \times \text{Distance}$$

You can use the work formula to calculate the amount of work you do to lift a plant. When you lift an object, the upward force you exert must be at least equal to the object's weight. So, to lift the lighter plant, you would have to exert a force of 50 newtons. The distance you lift the plant is 0.5 meters. The amount of work you do on the plant can be calculated using the work formula.

$$\text{Work} = \text{Force} \times \text{Distance}$$
$$\text{Work} = 50\ \text{N} \times 0.5\ \text{m} = 25\ \text{N}\cdot\text{m}$$

To lift the heavier plant, you would have to exert a force of 100 newtons. So the amount of work you do would be 100 newtons × 0.5 meters, or 50 N·m. As you can see, you do more work to lift the heavier object.

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When force is measured in newtons and distance in meters, the SI unit of work is the newton × meter (N•m). This unit is also called a joule (JOOL) in honor of James Prescott Joule, a physicist who studied work in the mid-1800s. One **joule** (J) is the amount of work you do when you exert a force of 1 newton to move an object a distance of 1 meter. You would have to exert 25 joules of work to lift the lighter plant and 50 joules of work to lift the heavier plant.

**Reading Checkpoint** **What is the SI unit for work?**

## Power

The amount of work you do on an object is not affected by the time it takes to do the work. For example, if you carry a backpack up a flight of stairs, the work you do is the weight of the backpack times the height of the stairs. Whether you walk or run up the stairs, you do the same amount of work because time is not part of the definition of work.

But time is important when you talk about power. **Power** is the rate at which work is done. **Power equals the amount of work done on an object in a unit of time.** You need more power to run up the stairs with your backpack than to walk because it takes you less time to do the same work.

You can think of power in another way. An object that has more power than another object does more work in the same time. It can also mean doing the same amount of work in less time.

For example, a car's engine does work to accelerate the car from its rest position. The greater a car engine's power, the faster the engine can accelerate the car.

**Lab zone** **Try This Activity**

### Is Work Always the Same?

1. Obtain a pinwheel along with a hair dryer that has at least two power settings.
2. Set the dryer on its lowest setting. Use it to blow the pinwheel. Observe the pinwheel's motion.
3. Set the dryer on its highest setting. Again, blow the pinwheel and observe its motion.

**Inferring** Explain why work is done on the pinwheel. How are the two situations different? Is the amount of work done greater for the high or low setting? Why?

**FIGURE 4**
**Work and Power**
Whether you use a rake or a blower, the same amount of work is done to gather leaves. However, the blower has more power.
**Inferring** *Will the blower or the rake do the same amount of work in less time?*

**Calculating Power** Whenever you know how fast work is done, you can calculate power. Power is calculated by dividing the amount of work done by the amount of time it takes to do the work. This can be written as the following formula.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

Since work is equal to force times distance, you can rewrite the equation for power as follows.

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$


## Math Practice

1. **Calculating Power** A motor exerts a force of 12,000 N to lift an elevator 8.0 m in 6.0 seconds. What is the power of the motor?
2. **Calculating Power** A crane lifts an 8,000-N beam 75 m to the top of a building in 30 seconds. What is the crane's power?

## Math Sample Problem

### Calculating Power

A tow truck exerts a force of 11,000 N to pull a car out of a ditch. It moves the car a distance of 5 m in 25 seconds. What is the power of the tow truck?

**1 Read and Understand**

**What information are you given?**

Force of the tow truck ($F$) = 11,000 N

Distance ($d$) = 5.0 m

Time ($t$) = 25 s

**2 Plan and Solve**

**What quantity are you trying to calculate?**

The power ($P$) of the tow truck = ■

**What formula contains the given quantities and the unknown quantity?**

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

**Perform the calculation.**

$$\text{Power} = \frac{11{,}000 \text{ N} \times 5.0 \text{ m}}{25 \text{ s}}$$

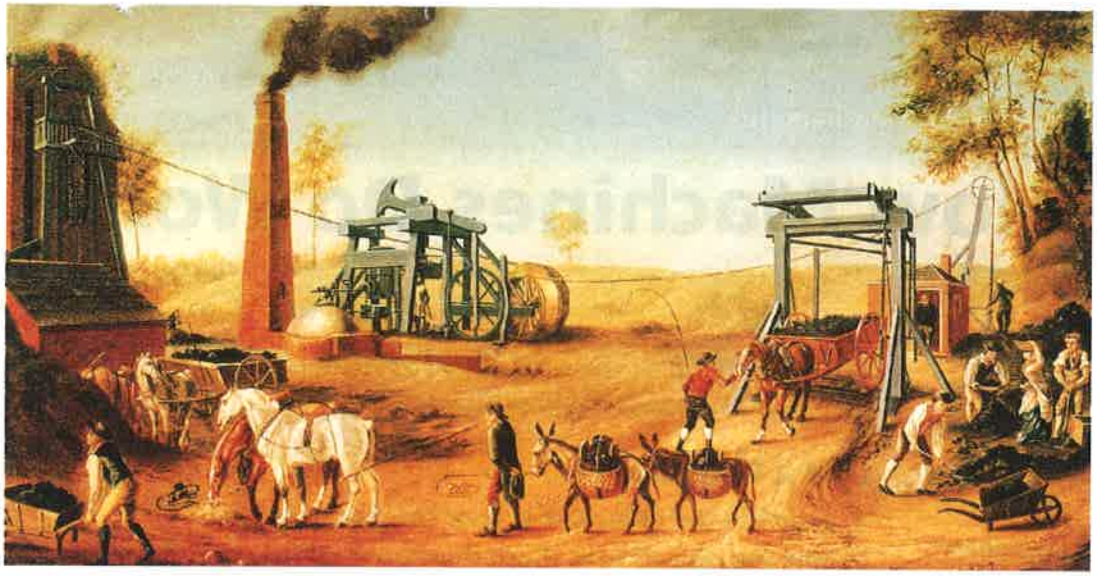
$$\text{Power} = \frac{55{,}000 \text{ N}\cdot\text{m}}{25 \text{ s}} \text{ or } \frac{55{,}000 \text{ J}}{25 \text{ s}}$$

$$\text{Power} = 2{,}200 \text{ J/s} = 2{,}200 \text{ W}$$

**3 Look Back and Check**

**Does your answer make sense?**

The answer tells you that the tow truck pulls the car with a power of 2,200 W. This value is about the same power of three horses, so the answer is reasonable.



**Power Units** When work is measured in joules and time in seconds, the SI unit of power is the joule per second (J/s). This unit is also known as the watt (W), in honor of James Watt, who made great improvements to the steam engine. One joule of work done in one second is one watt of power. In other words, 1 J/s = 1 W.

A watt is a relatively small unit of power. Because a watt is so small, power is often measured in larger units. One kilowatt (kW) equals 1,000 watts.

When people talk about engines for vehicles, they use another power unit instead of the watt. This unit is the horsepower. One horsepower equals 746 watts. (The horsepower is not an SI unit.)

**FIGURE 5**
**Horsepower**
James Watt used the word *horsepower* to advertise the advantages of his improved steam engine (next to the chimney) of 1769.

**Reading Checkpoint** What is a kilowatt?

## Section 1 Assessment

**Target Reading Skill Asking Questions** Use the answers to the questions you wrote about the headings to help you answer the questions below.

### Reviewing Key Concepts

1. a. **Reviewing** What is work?
   b. **Describing** In order for work to be done on an object, what must happen to the object?
   c. **Applying Concepts** In which of the following situations is work being done: rolling a bowling ball, pushing on a tree for ten minutes, kicking a football?
2. a. **Identifying** What is a joule?
   b. **Explaining** How can you determine the amount of work done on an object?
   c. **Problem Solving** Is more work done when a force of 2 N moves an object 3 m or when a force of 3 N moves an object 2 m? Explain.
3. a. **Defining** What is power?
   b. **Summarizing** How are power and work related?

### Math Practice

4. **Calculating Power** Your laundry basket weighs 22 N and your room is 3.0 m above you on the second floor. It takes you 6.0 seconds to carry the laundry basket up. What is your power?
5. **Calculating Power** If you take only 4.4 seconds to carry the basket upstairs, what is your power?

Section 2

Integrating Mathematics

# How Machines Do Work

## Reading Preview

### Key Concepts

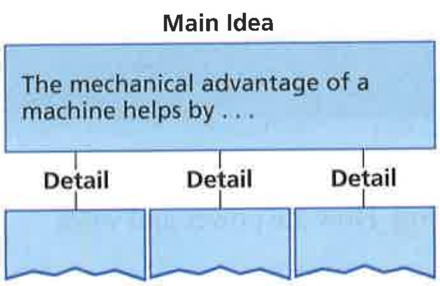
- How do machines make work easier?
- What is a machine's mechanical advantage?
- How can you calculate the efficiency of a machine?

### Key Terms

- machine
- input force
- output force
- input work
- output work
- mechanical advantage
- efficiency

### Target Reading Skill

**Identifying Main Ideas** As you read the What Is a Machine? section, write the main idea in a graphic organizer like the one below. Then write three supporting details.




## Lab zone Discover Activity

### Is It a Machine?

1. Examine the objects that your teacher gives you.
2. Sort the objects into those that are machines and those that are not machines.
3. Determine how each object that you classified as a machine functions. Explain each object to another student.

**Think It Over**

**Forming Operational Definitions** Why did you decide certain objects were machines while other objects were not?

A load of soil for your school garden has been dumped 10 meters from the garden. How can you move the soil easily and quickly? You could move the soil by handfuls, but that would take a long time. Using a shovel would make the job easier. If you had a wheelbarrow, that would make the job easier still! But be careful what you think. Using a machine may make work go faster, but it doesn't mean you do less work.

**FIGURE 6**
**Using Machines**
Shovels and rakes make the work of these students easier.

## What Is a Machine?

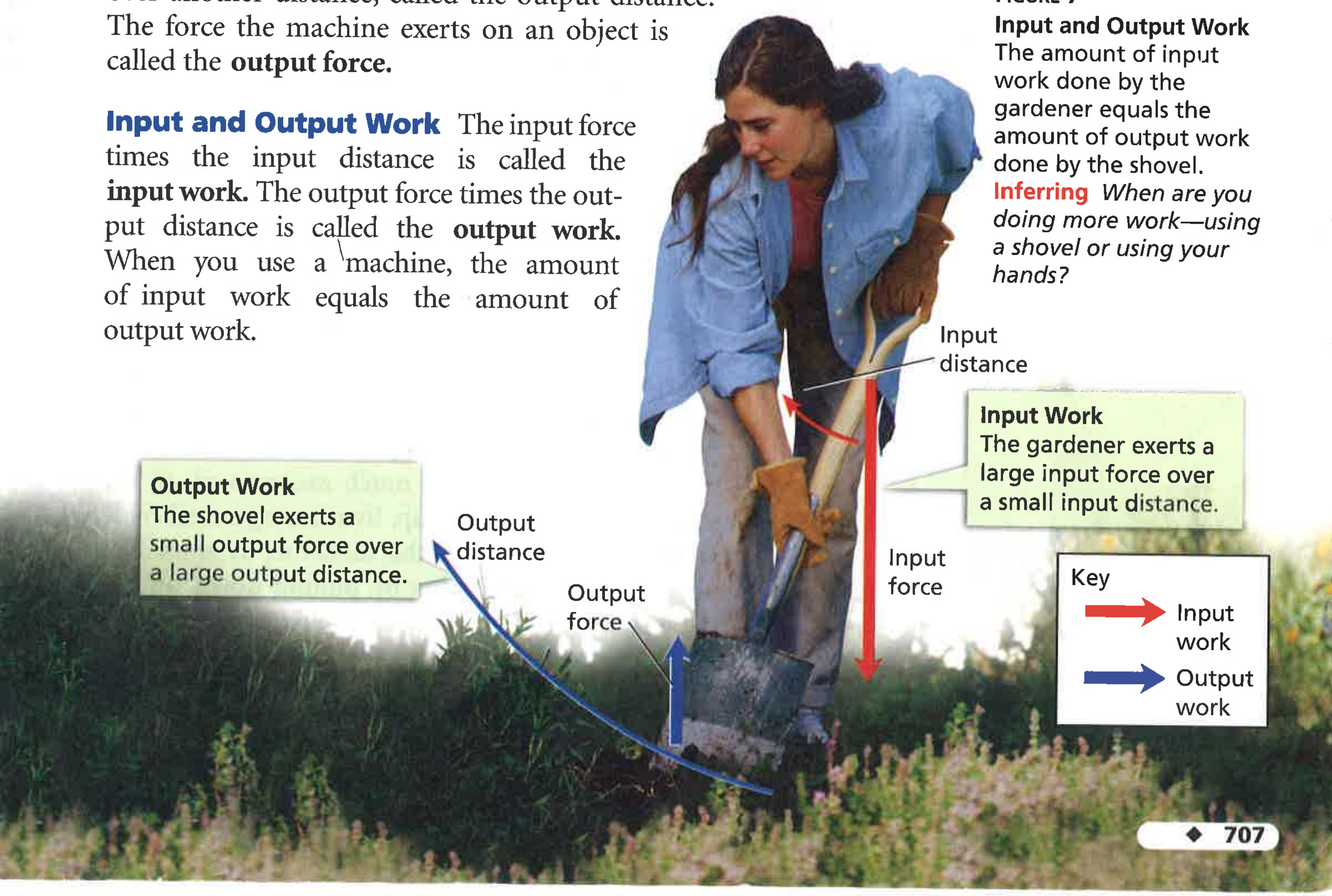
Shovels and wheelbarrows are two examples of machines. A **machine** is a device that allows you to do work in a way that is easier or more effective. You may think of machines as complex gadgets with motors, but a machine can be quite simple. For example, think about using a shovel. A shovel makes the work of moving soil easier, so a shovel is a machine.

Moving a pile of soil will involve the same amount of work whether you use your hands or a shovel. What a shovel or any other machine does is change the way in which work is done. **A machine makes work easier by changing at least one of three factors. A machine may change the amount of force you exert, the distance over which you exert your force, or the direction in which you exert your force.** In other words, a machine makes work easier by changing either force, distance, or direction.

**Input and Output Forces** When you use a machine to do work, you exert a force over some distance. For example, you exert a force on the shovel when you use it to lift soil. The force you exert on the machine is called the **input force.** The input force moves the machine a certain distance, called the input distance. The machine does work by exerting a force over another distance, called the output distance. The force the machine exerts on an object is called the **output force.**

**Input and Output Work** The input force times the input distance is called the **input work.** The output force times the output distance is called the **output work.** When you use a machine, the amount of input work equals the amount of output work.

**FIGURE 7**
**Input and Output Work**
The amount of input work done by the gardener equals the amount of output work done by the shovel.
**Inferring** *When are you doing more work—using a shovel or using your hands?*



## Lab zone Try This Activity

### Going Up

Does a rope simply turn your force upside down? Find out!

1. Tie a piece of string about 50 cm long to an object, such as an empty cooking pot. Make a small loop on the other end of the string.
2. Using a spring scale, slowly lift the pot 20 cm. Note the reading on the scale.
3. Now loop the string over a pencil and pull down on the spring scale to lift the pot 20 cm. Note the reading on the scale.

**Developing Hypotheses** How did the readings on the spring scale compare? If the readings were different, suggest a reason why. What might be an advantage to using this system?

**Changing Force** In some machines, the output force is greater than the input force. How can this happen? Recall the formula for work: Work = Force × Distance. If the amount of work stays the same, a decrease in force must mean an increase in distance. So if a machine allows you to use less input force to do the same amount of work, you must apply that input force over a greater distance.

What kind of machine allows you to exert a smaller input force? Think about a ramp. Suppose you have to lift a heavy box onto a stage. Instead of lifting the box, you could push it up a ramp. Because the length of the ramp is greater than the height of the stage, you exert your input force over a greater distance. However, when you use the ramp, the work is easier because you can exert a smaller input force. The faucet knob in Figure 8 changes force in the same way.

**Changing Distance** In some machines, the output force is less than the input force. Why would you want to use a machine like this? This kind of machine allows you to exert your input force over a shorter distance. In order to apply a force over a shorter distance, you need to apply a greater input force.

When do you use this kind of machine? Think about taking a shot with a hockey stick. You move your hands a short distance, but the other end of the stick moves a greater distance to hit the puck. When you use chopsticks to eat your food, you move the hand holding the chopsticks a short distance. The other end of the chopsticks moves a greater distance, allowing you to pick up and eat food. When you ride a bicycle in high gear, you apply a force to the pedals over a short distance. The bicycle, meanwhile, travels a much longer distance.

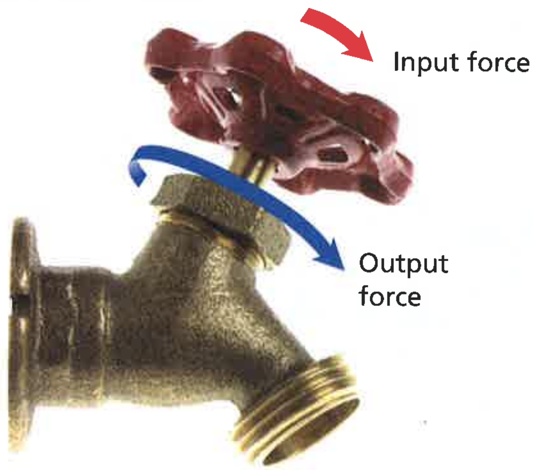
**Changing Direction** Some machines don't change either force or distance. What could be the advantage of these machines? Well, think about a weight machine. You could stand and lift the weights. But it is much easier to sit on the machine and pull down than to lift up. By running a steel cable over a small wheel at the top of the machine, as shown in Figure 8, you can raise the weights by pulling down on the cable. This cable system is a machine that makes your job easier by changing the direction in which you exert your force.

**Reading Checkpoint** How does the cable system on a weight machine make raising the weights easier?

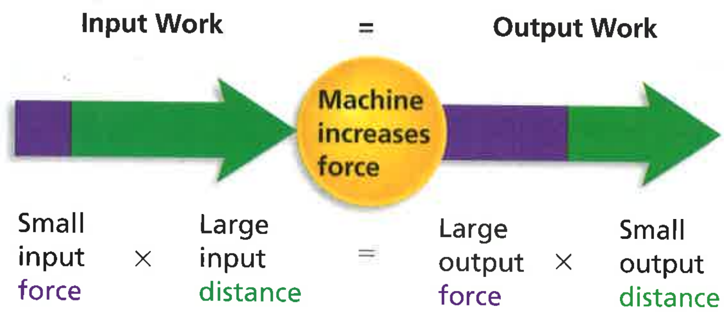
**FIGURE 8**

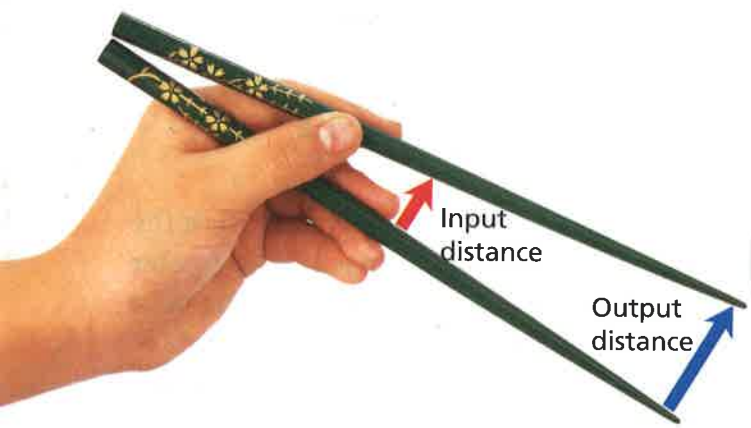
## Making Work Easier

A machine can make work easier in one of three ways.

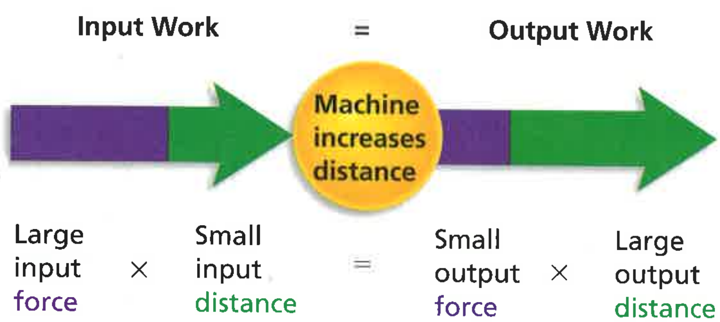


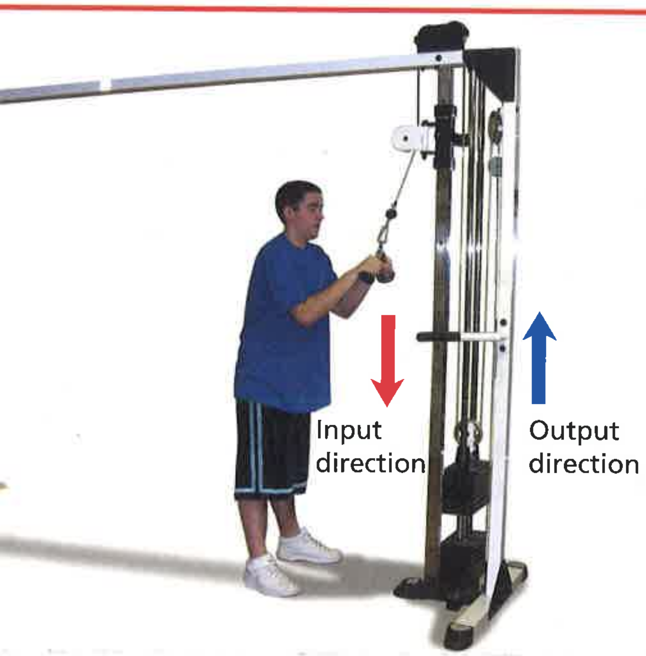

When a machine increases force, you must exert the input force over a greater distance.




When a machine increases distance, you must apply a greater input force.




When a machine changes the direction of the input force, the amount of force and the distance remain the same.

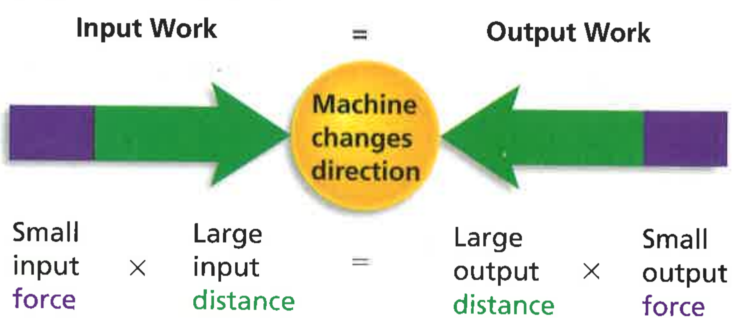


**FIGURE 9**
**Mechanical Advantage**
Without the mechanical advantage of the can opener, opening the can would be very difficult.

## Mechanical Advantage

If you compare the input force to the output force, you can find the advantage of using a machine. **A machine's mechanical advantage is the number of times a machine increases a force exerted on it.** Finding the ratio of output force to input force gives you the **mechanical advantage** of a machine.

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

**Increasing Force** When the output force is greater than the input force, the mechanical advantage of a machine is greater than 1. Suppose you exert an input force of 10 newtons on a hand-held can opener, and the opener exerts an output force of 30 newtons on a can. The mechanical advantage of the can opener is

$$\frac{\text{Output force}}{\text{Input force}} = \frac{30\ \text{N}}{10\ \text{N}} = 3$$

The can opener triples your input force!

**Increasing Distance** For a machine that increases distance, the output force is less than the input force. So in this case, the mechanical advantage is less than 1. For example, suppose your input force is 20 newtons and the machine's output force is 10 newtons. The mechanical advantage is

$$\frac{\text{Output force}}{\text{Input force}} = \frac{10\ \text{N}}{20\ \text{N}} = 0.5$$

The output force of the machine is half your input force, but the machine exerts that force over a longer distance.

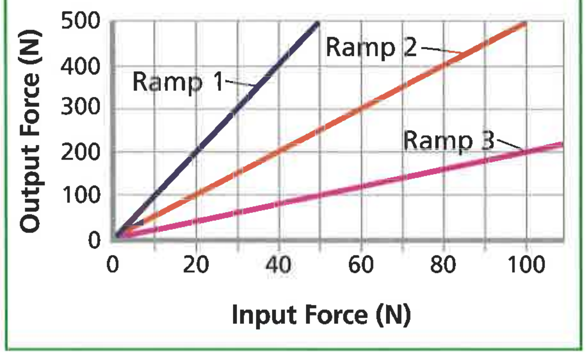
## Math Analyzing Data

### Mechanical Advantage

The input force and output force for three different ramps are shown in the graph.

1. **Reading Graphs** What variable is plotted on the horizontal axis?
2. **Interpreting Data** If an 80-N input force is exerted on Ramp 2, what is the output force?
3. **Interpreting Data** Find the slope of the line for each ramp.
4. **Drawing Conclusions** Why does the slope represent each ramp's mechanical advantage? Which ramp has the greatest mechanical advantage?

**Mechanical Advantages of Ramps**




**Changing Direction** What can you predict about the mechanical advantage of a machine that changes the direction of the force? If only the direction changes, the input force will be the same as the output force. The mechanical advantage will always be 1.

## Efficiency of Machines

So far, you have learned that the work you put into a machine is exactly equal to the work done by the machine. In an ideal situation, this equation is true. In real situations, however, the output work is always less than the input work.

**Friction and Efficiency** If you have ever tried to cut something with scissors that barely open and close, you know that a large part of your work is wasted overcoming the tightness, or friction, between the parts of the scissors.

In every machine, some work is wasted overcoming the force of friction. The less friction there is, the closer the output work is to the input work. The **efficiency** of a machine compares the output work to the input work. Efficiency is expressed as a percent. The higher the percent, the more efficient the machine is. If you know the input work and output work for a machine, you can calculate a machine's efficiency.

**Reading Checkpoint** **Why is output work always less than input work in real situations?**

FIGURE 10
**Efficiency**
A rusty pair of shears is less efficient than a new pair of shears.
**Applying Concepts** *What force reduces the efficiency of the shears?*

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**Calculating Efficiency** **To calculate the efficiency of a machine, divide the output work by the input work and multiply the result by 100 percent.** This is summarized by the following formula.

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

If the tight scissors described above have an efficiency of 60%, only a little more than half of the work you do goes into cutting the paper. The rest is wasted overcoming the friction in the scissors.

## Math Sample Problem

### Calculating Efficiency

You do 250,000 J of work to cut a lawn with a hand mower. If the work done by the mower is 200,000 J, what is the efficiency of the lawn mower?

**1 Read and Understand.**

**What information are you given?**

Input work ($W_{input}$) = 250,000 J

Output work ($W_{output}$) = 200,000 J

**2 Plan and Solve**

**What quantity are you trying to calculate?**

The efficiency of the lawn mower = ■

**What formula contains the given quantities and the unknown quantity?**

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

**Perform the calculation.**

$$\text{Efficiency} = \frac{200{,}000 \text{ J}}{250{,}000 \text{ J}} \times 100\%$$

$$\text{Efficiency} = 0.8 \times 100\% = 80\%$$

**The efficiency of the lawn mower is 80%.**

**3 Look Back and Check**

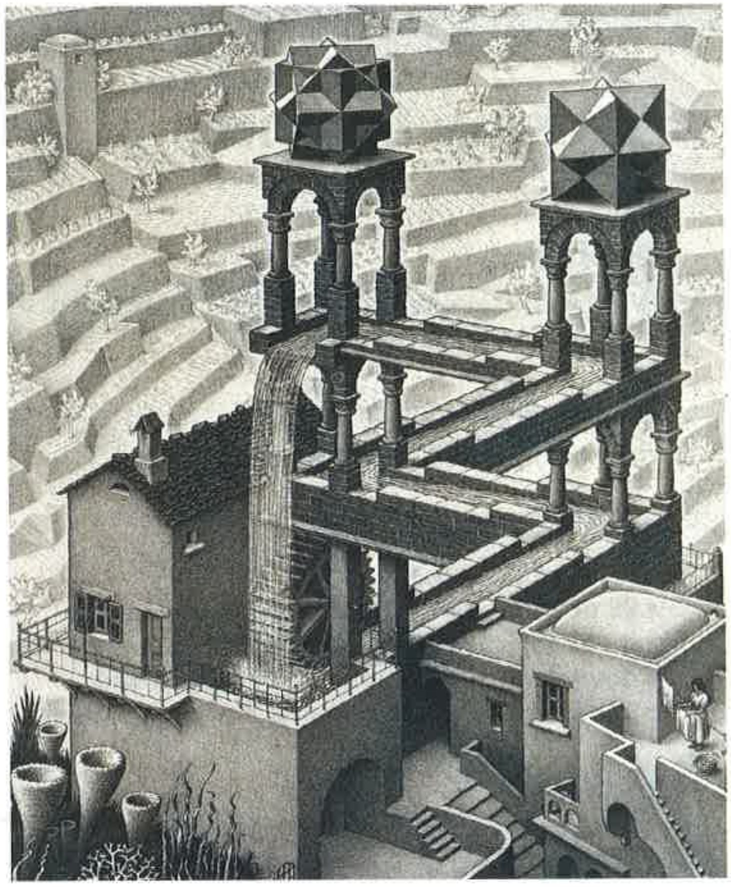
**Does your answer make sense?**

An efficiency of 80% means that 80 out of every 100 J of work went into cutting the lawn. This answer makes sense because most of the input work is converted to output work.

## Math Practice

1. **Calculating Efficiency** You do 20 J of work while using a hammer. The hammer does 18 J of work on a nail. What is the efficiency of the hammer?
2. **Calculating Efficiency** Suppose you left your lawn mower outdoors all winter. Now it's rusty. Of your 250,000 J of work, only 100,000 J go to cutting the lawn. What is the efficiency of the lawn mower now?

**FIGURE 11**
**An Ideal Machine?**
M. C. Escher's print *Waterfall* illustrates an ideal machine. **Inferring** *Why won't Escher's waterfall machine work in real life?*



**Real and Ideal Machines** If you could find a machine with an efficiency of 100%, it would be an ideal machine. Unfortunately, an ideal machine, such as the one shown in Figure 11, does not exist. In all machines, some work is wasted due to friction. So all machines have an efficiency of less than 100%. The machines you use every day, such as scissors, screwdrivers, and rakes, lose some work due to friction.

A machine's ideal mechanical advantage is its mechanical advantage with 100% efficiency. However, if you measure a machine's input force and output force, you will find the efficiency is always less than 100%. A machine's measured mechanical advantage is called actual mechanical advantage.

**Reading Checkpoint** **What is a machine's ideal mechanical advantage?**

## Section 2 Assessment

### Target Reading Skill

**Identifying Main Ideas** Use your graphic organizer to help you answer Question 1 below.

### Reviewing Key Concepts

1. a. **Defining** What is a machine?
   b. **Describing** In what three ways can machines make work easier?
   c. **Applying Concepts** How does a screwdriver make work easier?
2. a. **Reviewing** What is the mechanical advantage of a machine?
   b. **Making Generalizations** What is the mechanical advantage of a machine that changes only the direction of the applied force?
   c. **Calculating** If a machine has an input force of 40 N and an output force of 80 N, what is its mechanical advantage?
3. a. **Reviewing** What must you know in order to calculate a machine's efficiency?
   b. **Explaining** What is an ideal machine?
   c. **Comparing and Contrasting** How is a real machine like an ideal machine, and how is it different?

### Math Practice

4. **Calculating Efficiency** The input work you do on a can opener is 12 J. The output work the can opener does is 6 J. What is the efficiency of the can opener?
5. **Calculating Efficiency** Suppose the efficiency of a manual pencil sharpener is 58%. If the output work needed to sharpen a pencil is 4.8 J, how much input work must you do to sharpen the pencil?

Lab zone **Skills Lab**

# Seesaw Science

## Problem

What is the relationship between distance and weight for a balanced seesaw?

## Skills Focus

controlling variables, interpreting data

## Materials

- meter stick
- masking tape
- 28 pennies, minted after 1982
- small object with a mass of about 50 g
- dowel or other cylindrical object for pivot point, about 10 cm long and 3 cm in diameter

## Procedure

1. Begin by using the dowel and meter stick to build a seesaw. Tape the dowel firmly to the table so that it does not roll.
2. Choose the meter stick mark that will rest on the dowel from the following: 55 cm or 65 cm. Record your choice. Position your meter stick so that it is on your chosen pivot point with the 100-cm mark on your right.
3. Slide the 50-g mass along the shorter end of the meter stick until the meter stick is balanced, with both sides in the air. (This is called "zeroing" your meter stick.)
4. Copy the data table into your notebook.
5. Place a stack of 8 pennies exactly over the 80-cm mark. Determine the distance, in centimeters, from the pivot point to the pennies. Record this distance in the "Distance to Pivot" column for the right side of the seesaw.
6. Predict where you must place a stack of 5 pennies in order to balance the meter stick. Test your prediction and record the actual position in the "Position of Pennies" column for the left side of the seesaw.