Name _____ Class _____ Date _____

CHAPTER 4 Work and Machines

SECTION 2

What Is a Machine?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a machine?
- How does a machine make work easier?
- What is mechanical advantage?
- What is mechanical efficiency?

What Is a Machine?

Imagine changing a flat tire without a jack to lift the car or a tire iron to remove the bolts. Would it be easy? No, you would need several people just to lift the car! Sometimes you need the help of machines to do work. A **machine** is something that makes work easier. It does this by lowering the size or direction of the force you apply. ☑

When you hear the word machine, what kind of objects do you think of? Not all machines are hard to use. You use many simple machines every day. Think about some of these machines. The following table lists some jobs you use a machine to do.

Work	Machine you could use
Removing the snow in your driveway	
Getting you to school in the morning	
Painting a room	
Picking up the leaves from your front yard	
Drying your hair	

STUDY TIP

Brainstorm Think of ways that machines make your work easier and write them down in your science notebook.

READING CHECK

1. Describe How does a machine make work easier?

_____

_____

_____

TAKE A LOOK

2. Identify Complete the table by filling in the last column.

Two Examples of Everyday Machines

Wheelchair

Scissors

How Do Machines Make Work Easier?

You can use a simple machine, such as a screwdriver, to remove the lid from a paint can. An example of this is shown in the figure below. The screwdriver is a type of *lever*. The tip of the screwdriver is put under the lid and you push down on the screwdriver. The tip of the screwdriver lifts the lid as you push down. In other words, you do work on the screwdriver, and the screwdriver does work on the lid.

WORK IN, WORK OUT

When you use a machine, you do work and the machine does work. The work you do on a machine is called the **work input**. The force you apply to the machine to do the work is the *input force*. The work done by the machine on another object is called the **work output**. The force the machine applies to do this work is the *output force*. ☑

READING CHECK

3. Identify What is work input? What is work output?

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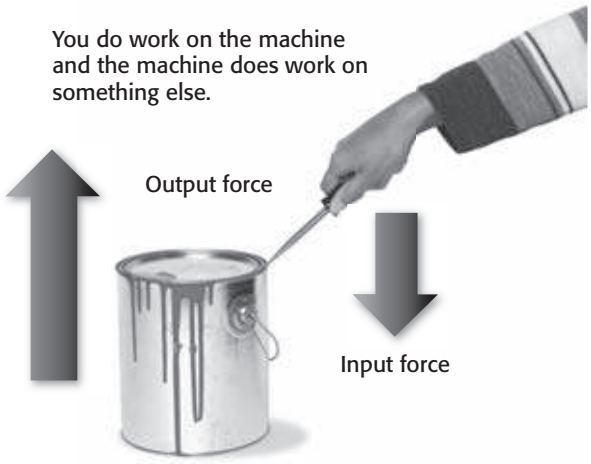

TAKE A LOOK

4. Identify What is the force you put on a screwdriver called?

_____

What is the force the screwdriver puts on the lid called?

_____

HOW MACHINES HELP

Machines do not decrease the amount of work you do. Remember that work equals the force applied times the distance ($W = F \times d$). Machines lower the force that is needed to do the same work by increasing the distance the force is applied. This means less force is needed to do the same work.

In the figure above, you apply a force to the screwdriver and the screwdriver applies a force to the lid. The force the screwdriver puts on the lid is greater than the force you apply. Since you apply this force over a greater distance, your work is easier. ☑

READING CHECK

5. Identify To make work easier, what force is lowered?

_____

SAME WORK, DIFFERENT FORCE

Machines make work easier by lowering the size or direction (or both) of the input force. A machine doesn't change the amount of work done. A ramp can be used as a simple machine shown in the figure below. In this example a ramp makes work easier because the box is pushed with less force over a longer distance.

Input Force and Distance

The boy lifts the box. The input force is the same as the weight of the box.

The girl uses a ramp to lift the box. The input force is the less than the weight of the box. She applies this force for a longer distance.

Look at the boy lifting a box in the figure above. Suppose the box weighs 450 N and is lifted 1 m. How much work is done to move the box?

Step 1: Write the equation.

$$W = F \times d$$

Step 2: Place values into the equation, and solve.

$$W = 450\ \text{N} \times 1\ \text{m} = 450\ \text{N}\times\text{m}, \text{ or } 450\ \text{J}$$

Look at the girl using a ramp. Suppose the force to push the box is 150 N. It is pushed 3 m. How much work is done to move the box?

Step 1: Write the equation.

$$W = F \times d$$

Step 2: Place values into the equation, and solve.

$$W = 150\ \text{N} \times 3\ \text{m} = 450\ \text{N}\times\text{m}, \text{ or } 450\ \text{J}$$

Work done to move box is 450 J.

The same amount of work is done with or without the ramp. The boy uses more force and a shorter distance to lift the box. The girl uses less force and a longer distance to move the box. They each use a different force and a different distance to do the same work.

TAKE A LOOK

6. Describe Notice that the box is lifted the same distance by the boy and the girl. Which does more work on the box?

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Math Focus

7. Calculate How much work is done when a 50 N force is applied to a 0.30 m screwdriver to lift a paint can lid?

FORCE AND DISTANCE CHANGE TOGETHER

When a machine changes the size of the output force, the distance must change. When the output force increases, the distance the object moves must decrease. This is shown in the figure of the nutcracker below. The handle is squeezed with a smaller force than the output force that breaks the nut. So, the output force is applied over a smaller distance.

Math Focus

8. Explain Why is the input arrow shorter than the output arrow in the photo of the nutcracker? Why are the arrows the same length in the figure of the pulley?

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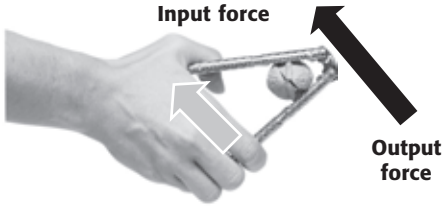
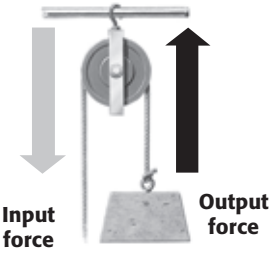
Machines Change the Size and/or Direction of a Force



A nutcracker increases the force but applies it over a shorter distance.



A simple pulley changes the direction of the input force, but the size of the output force is the same as the input force.

What Is Mechanical Advantage?

Some machines can increase the size of the force more than others. A machine's **mechanical advantage** tells you how much the force increases. The mechanical advantage compares the input force with the output force.

CALCULATING MECHANICAL ADVANTAGE

A machine's mechanical advantage can be calculated by using the following equation:

$$mechanical\ advantage\ (MA) = \frac{output\ force}{input\ force}$$

Math Focus

9. Calculate What is the mechanical advantage of a nutcracker if the input force is 65 N and the output force is 130 N?

Look at this example. You push a box weighing 500 N up a ramp (output force) by applying 50 N of force. What is the mechanical advantage of the ramp?

Step 1: Write the equation.

$$mechanical\ advantage\ (MA) = \frac{output\ force}{input\ force}$$

Step 2: Place values into the equation, and solve.

$$MA = \frac{500\ \text{N}}{50\ \text{N}} = 10$$

The mechanical advantage of the ramp is 10.

What Is a Machine's Mechanical Efficiency?

No machine changes all of the input work into output work. Some of the work done by the machine is lost to *friction*. Friction is always present when two objects touch. The work done by the machine plus the work lost to friction is equal to the work input. This is known as the *Law of Conservation of Energy*.

The **mechanical efficiency** of a machine compares a machine's work output with the work input. A machine is said to be efficient if it doesn't lose much work to friction.

CALCULATING MECHANICAL EFFICIENCY

A machine's mechanical efficiency is calculated using the following equation:

$$mechanical\ advantage\ (MA) = \frac{output\ force}{input\ force} \times 100$$

The 100 in the equation means that mechanical efficiency is written as a percentage. It tells you the percentage of work input that gets done as work output.

Let's try a problem. You do 100 J of work on a machine and the work output is 40 J. What is the mechanical efficiency of the machine?

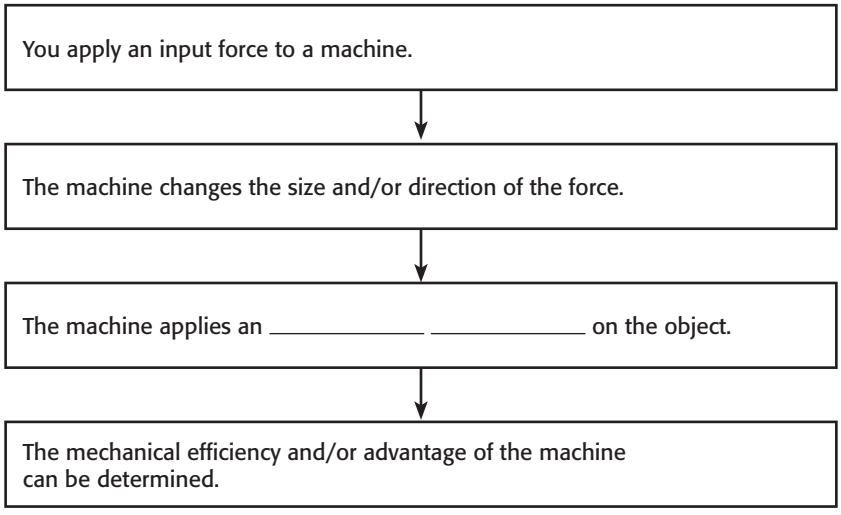
Step 1: Write the equation.

$$mechanical\ effeciency\ (ME) = \frac{work\ output}{work\ input} \times 100$$

Step 2: Place values into the equation, and solve.

$$ME = \frac{40\ \text{J}}{100\ \text{J}} \times 100 = 40\%$$

Process Chart



Math Focus

10. Calculate What is the mechanical efficiency of a simple pulley if the input work is 100 N and the output work is 90 N?

Math Focus

11. Identify Fill in the missing words on the process chart.

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Section 2 Review

SECTION VOCABULARY

machine a device that helps do work by either overcoming a force or changing the direction of the applied force	**work input** the work done on a machine; the product of the input force and the distance through which the force is exerted
mechanical advantage a number that tells how many times a machine multiplies force	**work output** the work done by a machine; the product of the output force and the distance through which the force is exerted
mechanical efficiency a quantity, usually expressed as a percentage, that measures the ratio of work output to work input in a machine	

1. **Explain** Why is it easier to move a heavy box up a ramp than it is to lift the box off the ground?

2. **Identify** What are the two ways that a machine can make work easier?

3. **Compare** What is the difference between work input and work output?

4. **Calculate** You apply an input force of 20 N to a hammer that applies an output force of 120 N to a nail. What is the mechanical advantage of the hammer? Show your work.

5. **Explain** Why is a machine's work output always less than the work input?

6. **Calculate** What is the mechanical efficiency of a machine with a work input of 75 J and a work output of 25 J? Show your work.

SECTION 2 WHAT IS A MACHINE?

1. by lowering the size or direction of the force applied
2. Removing the snow in your driveway: snow-shovel, plow, snowblower

   Getting you to school in the morning: bus, car, van, bike, skateboard

   Painting a room: paint brush, roller

   Picking up the leaves from your front yard: rake, lawnmower, leafblower

   Drying your hair: hair dryer
3. the work you do on a machine; the work done by a machine
4. input force, output force
5. the force you apply
6. They both do the same amount of work on the box.
7. $W = F \times d = 50\ \text{N} \times 0.30\ \text{m} = 15\ \text{J}$
8. The input force is less than the output force. The input force equals output force.
9. $MA = \dfrac{\textit{output force}}{\textit{input force}} = \dfrac{130\ \text{N}}{65\ \text{N}} = 2$
10. $ME = \dfrac{\textit{work output}}{\textit{work input}} \times 100$

    $ME = \dfrac{90\ \text{N}}{100\ \text{N}} \times 100 = 90\%$
11. output force

Review

1. A ramp decreases the force you need to apply to the object. You do the same work but over a longer distance.
2. A machine changes the size or the direction of the force.
3. The work input is the work you do on the machine. The work output is the work the machine does on another object.
4. $MA = \dfrac{\textit{output force}}{\textit{input force}} = \dfrac{120\ \text{N}}{20\ \text{N}} = 6$
5. Some of the work done by a machine is used to overcome friction.
6. $ME = \dfrac{\textit{work output}}{\textit{work input}} \times 100$

   $ME = \dfrac{25\ \text{J}}{75\ \text{J}} \times 100 = 0.33\%$

SECTION 3 TYPES OF MACHINES

1. An input force is applied to a bar that rotates at the fulcrum to lift a load.
2. The mechanical advantage would decrease because the distance to the load is increased.
3. In a second-class lever, the load is between the fulcrum and the input force. It does not change the direction of the input force.
4. The output force is always less than the input force.
5. a simple machine with a grooved wheel that holds a rope or cable
6. The output force is always the same as the input force.
7. 4
8. It will get smaller.
9. $MA = \dfrac{\textit{radius of wheel}}{\textit{radius of axle}}$

   $MA = \dfrac{75\ \text{cm}}{7.5\ \text{cm}} = 10$
10. An input force smaller than the object's weight is applied over a longer distance.
11. $MA = \dfrac{\textit{length of inclined plane}}{\textit{height of load raised}}$

    $MA = \dfrac{10\ \text{m}}{2.5\ \text{m}} = 4$
12. It would be larger.
13. a machine made of two or more simple machines
14. The lever cuts the can with a wedge. The wheel and axle move the wedge around the top of the can to cut it open.
15. They have many moving parts and a good deal of friction.

Review

1. First-class: The fulcrum is between the input force and the load.

    Second-class: The load is between the fulcrum and the input force.

    Center: There are a fulcrum, a load, and an input force.
2. $MA = \dfrac{\textit{radius of wheel}}{\textit{radius of axle}}$

   $MA = \dfrac{1.8\ \text{cm}}{0.6\ \text{cm}} = 3$
3. A wedge is a simple machine made of two moving inclined planes. A screw is an inclined plane wrapped around a cylinder.
4. the work output