UNIT B
Systems in Action

This rock climber, with his system of ropes and pulleys, enjoys the natural freshwater system of Ontario.

Unit Overview

Fundamental Concepts

In Science and Technology for grades 7 and 8, six fundamental concepts occur throughout. This unit addresses the following two:

- Systems and Interactions
- Continuity and Change

Big Ideas

As you work through this unit, you will develop a deeper understanding of the following big ideas:

- Systems are designed to accomplish tasks.
- All systems include an input and an output.
- Systems are designed to optimize human and natural resources.

Overall Expectations

By the end of this unit, you will be expected to:

1. assess the personal, social, and/or environmental impacts of a system, and evaluate improvements to a system and/or alternative ways of meeting the same needs
2. investigate a working system and the ways in which components of the system contribute to its desired function
3. demonstrate an understanding of different types of systems and the factors that contribute to their safe and efficient operation

Exploring

The da Vinci Surgical System® is a mechanical system used for robotic surgery.

Chances are that a system woke you up today and several systems helped you make your breakfast. You may also have used a transit system and a school system. A **system** is a group of individual parts or procedures that work together to accomplish a desired task. All the different parts of a system are called **components**. Society runs smoothly and efficiently because of its many systems.

Systems can be classified into two categories. A mechanical system is composed of physical parts working together, for example, a bus. The physical parts of the bus act together to provide transportation. A non-mechanical system is a set of procedures, methods, or rules that accomplish a task. Bus schedules and routes are examples of non-mechanical systems. Many systems in society include both mechanical and non-mechanical systems.

Some systems, such as the solar system, occur naturally. Other systems are developed to meet the needs of society. Many of those systems evolve as our society changes. One system that is continually changing is a health-care system.

Robotic Surgery

One recent addition to our health-care system is robotic surgery, the use of robots to perform surgery. Laparoscopic devices, such as fibre optic cables, miniature cameras, and surgical instruments, are inserted into the body through small incisions. These are controlled by the surgeon at a special console. This type of robotic surgery is called minimally invasive surgery (MIS). MIS surgery means less trauma and pain for the patient, who recovers more quickly.

Robotic surgery has now progressed to the point where a machine, instead of a surgeon, operates on a patient. The surgeon sits at a console and manipulates the robot's four arms. One robotic arm controls the camera while three arms manipulate the instruments. With this machine, surgeons have better precision and dexterity as well as full stereoscopic vision.

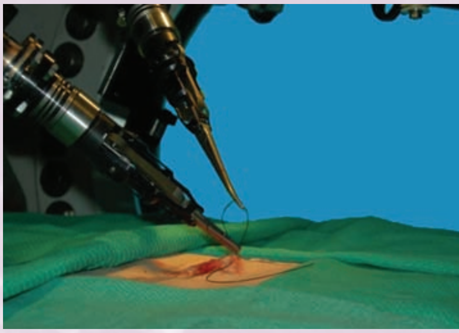
Dr. Anvari keeps an eye on the monitor while operating robotically.

Remote Surgery

With these new systems, surgery can now be done remotely, with the surgeon and the patient in different locations. In February 2003, Dr. Mehran Anvari of Hamilton, Ontario, operated on a patient in North Bay, over 400 km away. This was the first remote surgery (telesurgery) in Canada. The Canadian military may use remote surgery for injured soldiers in distant combat zones.

In the future, automatic surgery may be possible. The techniques of expert surgeons, stored in computers, will allow robot systems to perform surgery without direct human input.

Society has to decide if this is an ethical and acceptable addition to our medical system. Part of our responsibility as citizens is to assess each system's impact on society and on our environment.



The robotic instruments are closing the wound.

...MORE TO EXPLORE

B1 Quick Lab

Clothes Peg Surgery

In this lab, you will design something that works in the same way that robotic surgery does.

Purpose

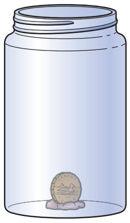
To design and construct a mechanical system to retrieve a coin from the bottom of a jar

Materials & Equipment

- glass jar
- $1 coin
- plasticine
- clothes peg

Procedure

1. Place a $1 coin (loonie) on edge in a small piece of plasticine. Place the plasticine and coin at the bottom of a tall jar.



2. Design a device to retrieve the coin from the jar using a clothes peg and other materials. Your device must allow you to pick up the coin without your fingers entering the jar.
3. Make a sketch of your design. Get your teacher's approval before you proceed.
4. Construct your device and attempt to pick up the coin from the bottom of the jar.

Questions

5. Was your design successful? (a) If yes, describe two modifications that could improve your design. (b) If no, suggest modifications to your design that might make it work properly.
6. Make a list of the components of your mechanical system and state their purposes in the overall task.

B2 Thinking about Science, Technology, Society, and the Environment

S T S E

Components of a System

Systems are made up of individual components that work together to perform a task or function.

What to Do

1. Choose one of the systems listed below.
   - health care system
   - legal system
   - school system
   - respiratory system
   - Aboriginal clan system
   - waste management system
2. List the components of this system.

Consider This

3. What task does this system perform?
4. Choose one component of the system from your list. Suppose that component was removed from the system. Describe how this would affect the system.
5. Describe the long-term effects of removing the component from the system. Include any societal, technological, and environmental impacts.

UNIT B

Contents

Unit Task

In your Unit Task, you will design, construct, and test a mechanical system that uses only the energy stored in a spring-bar mousetrap to perform a function other than catching mice. You will use skills that you learn in this unit to efficiently transfer the energy stored in the mousetrap. Your investigations on forces, work, mechanical advantage, and efficiency will help you develop your mechanical system.

Essential Question

How does a mousetrap work, and how does each component contribute to the system's desired function?

Getting Ready to Read

Thinking Literacy

Creating a Word Wall

Scan the unit and identify 10 key words whose meaning is unknown to you. Make a class list of unknown words. Arrange these words alphabetically and make them into a word wall. With your group, discuss possible meanings of each word. Think of related words to help you, then use the Glossary that starts on page 405 to verify your meanings. In your own words, record the meanings of your 10 unknown words in your notes.

4.0 Mechanical systems use forces to transfer energy.

In the circus, an acrobat jumps on one end of the teeter-totter to launch another acrobat into the air.

What You Will Learn

In this chapter, you will:

- describe the characteristics of a system and define a mechanical system
- identify the purpose, inputs, and outputs of a mechanical system
- explain how heat is produced
- understand the relationship between work, force, and distance moved

Skills You Will Use

In this chapter, you will:

- measure force using a spring scale
- calculate the work done to move objects
- calculate the mechanical advantage of a mechanical system

Why This Is Important

Riding a bike, climbing stairs, and throwing a ball are examples of using forces to transfer energy. Mechanical systems are often involved in these energy transformations.

Before Reading

Thinking Literacy

Activating Prior Knowledge

Chapter 4 focuses on four main topics: mechanical systems, force, work and energy, and mechanical advantage. Draw a mind map to record what you already know about each topic from earlier science classes, as well as from your daily life. Revisit your mind map as you read the chapter, and add and modify meanings and connections.

Key Terms

- work
- force
- friction
- mass
- weight
- mechanical system
- energy
- gravity
- mechanical advantage
- ideal mechanical advantage

4.0 Getting Started

Figure 4.1 The bike transfers the effort and motion of the clown's feet into a different motion for all the riders.

When we watch acrobats and clowns perform at a circus, we do not tend to think of science. But circus performers need to understand the science of mechanical systems in order to perform acts of strength and balance. A **mechanical system** is a group of physical parts that interact with each other. The parts function as a whole in order to complete a task.

The bicycle in Figure 4.1 is a mechanical system. Many individual parts of the bicycle work together to allow the clown to carry the passengers relatively easily. Although the clown's feet move in small circles, the bicycle is travelling in a straight line. As well, the clown can push hard enough on the pedals to move all the passengers.

Figure 4.2 If the riders sit at different distances from the centre, they can balance the teeter-totter.

Mechanical systems are more than just bicycles. Consider the teeter-totter in your local playground. The downward motion of one person is transferred into the upward motion of the other. By adjusting how far the two people sit from the centre of the board (the fulcrum), you can compensate for the people having different masses (Figure 4.2). Circus performers use a more complex version of the teeter-totter (Figure 4.3).

Figure 4.3 The smaller acrobat is able to move the larger acrobat by changing location.

B3 *Quick Lab*

Lift This

The human body is also a mechanical system. Muscles, bones, and joints work together to perform various tasks. Imagine that you have a ball in your hand. By controlling all the parts that make up your human mechanical system, you can move the ball in a circle or throw it in a straight line. Depending on how much effort you exert and the technique you use to throw the ball, you can control how fast the ball travels.

Purpose

To examine how the amount of effort required to lift a mass can vary depending on where the mass is located

Materials & Equipment

- piece of string, 50 cm long
- 1- to 2-kg mass

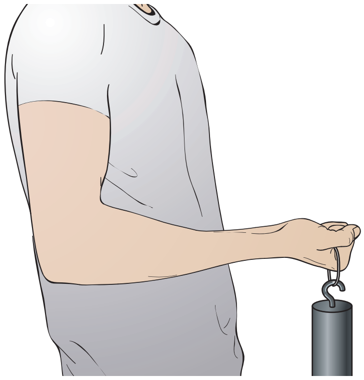


Figure 4.4

Procedure

1. Make a loop from the piece of string. Hang the mass from the string.
2. Stand up. Hold your forearm horizontally, with your elbow tight against the side of your body. Loop the string over your hand (Figure 4.4).
3. Keeping your elbow stationary, lift your arm slowly. Make mental notes of how much effort you need to lift the object and of the distance you were able to raise the object.
4. Move the loop of string to your wrist and repeat step 3.
5. Move the loop of string to your forearm and repeat step 3.

Questions

6. At which string location did you need the least effort to lift the object?
7. Explain the relationship between the distance of the string from your elbow and the amount of effort you required to lift the object.
8. Which string location allowed you to lift the object the farthest? Compare the effort needed at this location to those needed at the other locations.

4.1 Force

Here is a summary of what you will learn in this section:

- A force is a push or a pull that acts on an object.
- Forces can be classified as either contact forces or action-at-a-distance forces.
- Mass is the amount of matter in an object.
- Weight is the force of gravity acting on an object.
- For an object on Earth, the force of gravity, in newtons, is the product of the object's mass, in kilograms, and the gravitational field 9.8 N/kg.

"May the Force be with you" is a popular line from the *Star Wars* movies. The use of the word "force" in the movie is different from force in a science classroom. In science, **force** is a push or a pull that acts on an object.

B4 *Starting Point* Skills A C

Identifying Forces

Any object that is being pushed or pulled is experiencing a force. Looking at Figure 4.5, we could say, "The leash applies a force on the dog." With a partner, make a list of the forces that you can find in Figure 4.5.

Figure 4.5

In order to slide your textbook across your desk or kick a football, you must apply a force to the object (Figure 4.6). A magnet can move a steel paper clip without even touching it. Forces can also stop objects from moving, such as when you catch a ball. Even objects that are at rest have forces acting on them. For example, as you sit at your desk, you are being pulled to the ground by Earth's force of gravity. As well, your chair seat is pushing upward on you so that you do not fall. Every object in the universe experiences forces. So in terms of the *Star Wars* definition, the force is with you.

Figure 4.6 The football begins its motion as a result of the force of the player's foot.

Classifying Forces

All the different forces shown in Figure 4.5 can be classified as contact forces or action-at-a-distance forces.

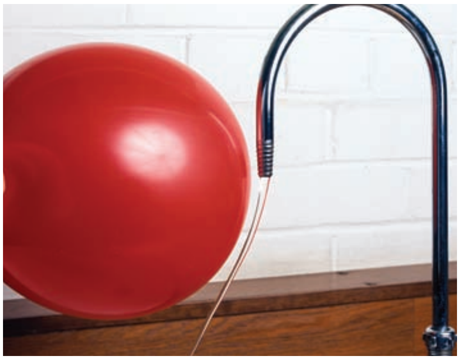
Contact forces must touch the object that they push or pull, for example, hitting a tennis ball (Figure 4.7). Another common contact force is friction. **Friction** is a force that opposes the relative motion of an object. If you slide a hockey puck across a wooden floor, it slows down and stops because friction resists its motion. If you slide the same hockey puck across ice instead of the floor, the puck slides farther before stopping because ice applies less friction on the puck than the wooden floor does.

Figure 4.7 The racket applies a contact force when hitting the ball.

Action-at-a-distance forces can push or pull an object without touching it. Gravity, static electricity, and magnetism produce action-at-a-distance forces, as shown in Figure 4.8. These are also called non-contact forces.

The most common action-at-a-distance force, the force of **gravity**, is the attraction between two objects due to their mass. The amount of attraction depends upon the amount of each object's mass and the distance between the two objects. For example, when we let go of a ball, the ball is pulled to the ground by the force of gravity, even though nothing is touching it. This is because the ball and Earth both have mass and therefore attract each other.

Figure 4.8 (a) The static charge on the balloon attracts the water. (b) Magnets apply an action-at-a-distance force.



(a)

(b)

B5 *During Reading*

Thinking Literacy

Making Connections

Making connections is an important strategy for readers. This ongoing process of interacting with the text helps readers connect with their prior experience and knowledge. This helps them visualize, infer, and remember what they have read better.

As you read the next section, record the following in a three-column chart:

1. key words that spark a meaningful connection
2. your connection as a reader
3. how this connection helps you better understand the text

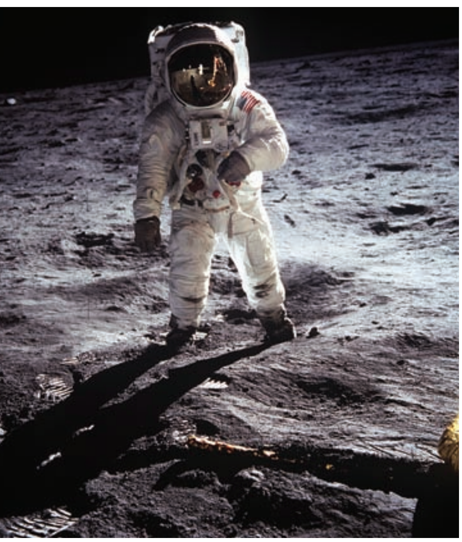


Figure 4.9 If you were an astronaut, your mass would be the same on both Earth and the Moon. Your weight would be less on the Moon, however, because the Moon has less gravity.

Mass

Once we have identified the type of force, we often need to measure the amount of force. Before we do this, we must understand the difference between mass and weight. **Mass** is the amount of matter in an object. The mass of a bowling ball is greater than the mass of a tennis ball because it contains more matter. The metric unit for measuring mass is the kilogram (kg). For example, the mass of 1 L of water is 1 kg. Smaller masses are often measured in grams (g). There are 1000 g in 1 kg, so we could say that the mass of 1 L of water is 1000 g.

Since mass is the amount of matter in an object, the object's mass does not change as a result of gravity. If you have a mass of 50 kg on Earth, your mass on the Moon, where gravity is one-sixth Earth's gravity, is still 50 kg (Figure 4.9). This is because the amount of matter in your body has not changed on your trip to the Moon.

Table 4.1 Masses and Weights of a 50-kg Person on the Surface of Various Objects in the Solar System.

Location	Mass (kg)	Weight (N)
Earth	50	490
Moon	50	80
Mars	50	160
Jupiter	50	1140

Weight

The weight of an object is not the same as its mass. **Weight** is the amount of force on an object due to gravity. Therefore, weight means the same thing as the force of gravity.

If you travelled from Earth to the Moon, your weight would change because the force of gravity on Earth is about six times stronger than the force of gravity on the Moon (Table 4.1). This means that your weight is about six times greater on Earth as it is on the Moon.

The Unit of Force

The metric unit for force is the newton (N), named after Sir Isaac Newton (1643–1727). Since weight is the force of gravity, it is measured in newtons (N). On Earth, a 1.0-kg mass has a weight of 9.8 N.

Outside of the science classroom, you may have used a scale to "weigh" fruit or vegetables. Most of these scales are marked in kilograms. When you do this, you are not finding the weight, in newtons, but instead finding the mass, in kilograms.

WORDS MATTER

The term "gravity" comes from the Latin "gravitas," meaning heavy. "Gravity" also means seriousness or solemnity, which is a different type of heaviness.

Measuring Force

Most meters that measure force contain a spring or elastic component that stretches or compresses when a force is applied. The most common force meter is called a Newton gauge or **spring scale**, as shown in Figure 4.10. A spring scale consists of a spring with a hook on the end. As more force is applied to the hook, the spring stretches farther. The spring scales used in your classroom have been calibrated to display the relationship between the amount of force and the distance of stretch. This allows you to read the amount of force directly from the spring scale.

Spring scales can measure forces other than weight. If you needed to know how much force you need to slide an object across your desk, you simply attach the spring scale to the object and pull at a constant speed, as in Figure 4.11. By pulling parallel to the desk at a constant speed, you are measuring the force of friction between the object and your desk.

Figure 4.10 The spring scale shows the weight of an object in newtons.

Suggested Activity •
B7 Quick Lab on page 103

Calculating the Force of Gravity (Weight)

It is useful to determine the weight of an object without having to use a spring scale. Scientists discovered that the mass of an object and its weight are directly proportional. That means that an object with twice the mass has twice the weight. On Earth, a 1.0-kg mass suspended from a spring scale has a weight of 9.8 N. A 2.0-kg mass has a weight of 19.6 N. Thus, if you multiply any mass by 9.8 N/kg, you get its weight on Earth. This value, 9.8 N/kg, is called Earth's gravitational field strength and is symbolized by g.

Figure 4.11 Spring scales can be used to determine the force required to move an object.

Take It Further

The bathroom scale you might use at home to weigh yourself does not look like the spring scale shown in Figure 4.10. Compare and contrast these two scales used for weighing. Begin your search at ScienceSource.

Suggested Activity

B8 Inquiry Activity on page 104

The force of gravity (F_g) on any mass (m) near the surface of Earth can be calculated by:

Force of gravity = (mass of object) × (the strength of Earth's gravitational field)

Using symbols, this word equation can be expressed as:

$$F_g = mg$$

where mass is in kilograms (kg) and g is 9.8 N/kg.

For example, to find the weight of a 50-kg student on Earth:

$$\begin{aligned} F_g &= mg \\ &= (50\text{ kg})(9.8\text{ N/kg}) \\ &= 490\text{ N} \end{aligned}$$

A 50-kg student weighs 490 N on Earth.

B6 Learning Checkpoint

Weight and Mass

1. Use the words "mass" or "weight" to correctly complete the following sentences.
   (a) Even if gravity changes, the _____ of an object does not change.
   (b) The ______ of an object would change if the gravity changed.
   (c) Kilogram (kg) is the metric unit for __________.
   (d) The newton (N) is the metric unit for __________.
2. The following masses are located on Earth. Calculate the weight of each object.
   (a) 25 kg
   (b) 40 kg
   (c) 150 kg
3. An object has a mass of 5.0 kg on the surface of the Moon. What would be the object's:
   (a) mass on Earth?
   (b) force of gravity on Earth?

B7 *Quick Lab*

Measuring Force with a Spring Scale

An object at rest requires a force to start it moving. To lift an object, a force must be applied that overcomes the force of gravity on that object. To slide an object across a surface, the applied force must overcome the force of friction. This force can be measured by using an appropriate spring scale.

Purpose

To measure the force required to move some common objects

Materials & Equipment

- different spring scales (0–5 N, 0–20 N)
- string
- scissors
- 4 small objects (less than 1 kg each)

CAUTION: Handle sharp objects like scissors very carefully.

Procedure

1. Copy Table 4.2 into your notebook.

Table 4.2 Measuring Force with a Spring Scale

Object	Force Required to Lift the Object (N)	Force Required to Slide the Object (N)

2. Choose four different objects from your backpack, pencil case, or classroom. Record the name of each object in your data table.
3. If any of the objects does not have a place to attach the hook of the spring scale, tie a loop of string to the object.
4. Place your first object on your desk and connect it to the hook of your smallest spring scale. Holding your spring scale vertically, slowly begin to lift the object with the spring scale. If the reading on the spring scale is approaching the maximum and the object is still on your desk, change to a larger spring scale. Measure the force required to lift the object and record this value in your data table.
5. Now reconnect your first object to the hook of your smallest spring scale. Holding your spring scale horizontally, slowly try to slide the object across your desk by pulling the spring scale. If the reading on the spring scale is approaching maximum and the object is still not moving, switch to a larger spring scale. Measure the force required to slide the object across your desk and record this value in your data table.
6. Repeat steps 4 and 5 for your remaining three objects.

Questions

7. If you needed approximately 3.0 N to lift an object, would it be better to use a 0–5 N scale or a 0–20 N scale? Explain your answer.
8. When measuring the force needed to slide your object, explain why it was important to hold the scale horizontally (parallel to the table) and not at an angle.
9. In general, does it take more force to lift an object off the desk or to slide the object across the desk?

DI Anchor Activity

B8 Inquiry Activity

Toolkits 2, 8

SKILLS YOU WILL USE
- Performing and reporting
- Analyzing and interpreting

The Force of Gravity

A graph is sometimes a good way to find the relationship between two variables. If the data produce a straight-line graph that passes through the origin, then we say that the two variables are directly proportional.

Question

What is the relationship between mass and the force of gravity (weight)?

Materials & Equipment

- spring scale
- set of hooked masses
- graph paper

Procedure

1. Copy Table 4.3 into your notebook, with space for five trials.

Table 4.3 The Force of Gravity

	Mass (g)	Mass (kg)	Weight (N)
1			
2			

2. Choose one of your hooked masses and record its mass, in grams, in the data table. Convert this value to kilograms and record this as its mass in kilograms.

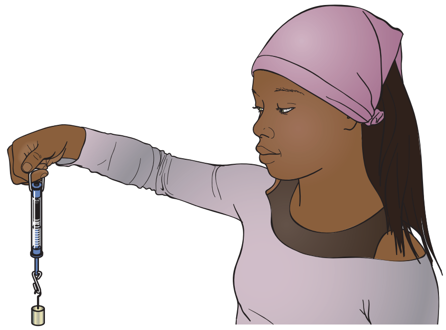


Figure 4.12

3. While holding your spring scale stationary vertically, hang the mass and measure its weight (Figure 4.12). Record this value in your data table.
4. Repeat steps 2 and 3 for four more masses. You may have to combine masses to get enough readings. For example, hook a 50-g and a 100-g mass together to get a 150-g mass.
5. Use your data to plot a weight-versus-mass graph. Plot the weight on the vertical axis and the mass, in kilograms, on the horizontal axis.
6. Draw a best-fit line through the data points plotted on your graph.

Analyzing and Interpreting

7. As you increased the mass, what happened to the weight?
8. Choose three points on the best-fit line of your graph. For each point, calculate the weight divided by the mass. Are the results of these three calculations similar to each other?
9. On Earth, the ratio of weight to mass is approximately 9.8 N/kg. How do your results compare to this ratio?
10. Did your best-fit line pass through all your data points? If no, what are some of the sources of error in your experiment?

Skill Builder

11. Explain how you could use your best-fit line to find the weight of a mass without hanging it from a spring scale.

Forming Conclusions

12. Your data are best represented by a straight line on a weight-versus-mass graph. What is the relationship between weight and mass?

4.1 CHECK and REFLECT

Key Concept Review

1. Define "force." State the correct units for measuring force.
2. What are the two categories of force? Give an example of a force for each category.
3. What force causes a sliding object to slow down?
4. What is another word for "force of gravity"?
5. Explain how weight is different from mass.
6. What device is commonly used to measure force?
7. You weigh yourself on your bathroom scale at home. Would the same scale give the same measurement if you weighed yourself on a different planet? Explain.

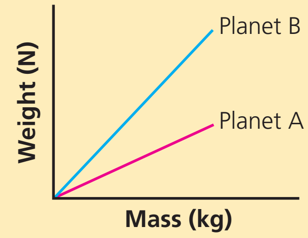
Connect Your Understanding

8. Calculate the weight, in newtons, of each of the following masses.

   (a) 25 kg (b) 6.0 kg (c) 250 g

Practise Your Skills

9. An astronaut measures the force of gravity on various masses on the surface of two different planets. The data for Planet A and Planet B are shown below. Which planet has the larger gravitational field? Explain your answer.



For more questions, go to ScienceSource.

B9 *Thinking about Technology, Society, and the Environment*

The Right Shoe

A lot of research goes into the design of shoes for specific sports, such as soccer shoes, bowling shoes, and basketball shoes. Often, the shoe is designed either to increase the force (e.g., a better grip in soccer shoes) or to decrease the force (e.g., shock absorption in basketball shoes and sliding ability in curling shoes).

Consider This

1. Choose a modern sports shoe. What need was the shoe designed to meet?
2. How has modern shoe technology affected the sport?
3. Did the development of this shoe have any economic impacts? environmental impacts? societal impacts?

4.2 Work and Energy

Here is a summary of what you will learn in this section:

- Work is done when a force causes something to move and energy is transferred.
- When a force causes an object to move a distance in the same direction as the force, then work = force × distance.
- Energy is the ability to do work.
- Kinetic energy is the energy due to an object's motion.
- Potential energy is stored energy.

Suppose you stopped 10 people on the street and asked them the question, "What is work?" For most people, work is what you do to earn money. You or your friends might work as baby sitters, newspaper deliverers, or hamburger flippers. What if your job was to hold a poster against a wall without moving? In this case, have you done work?

In science, the term "work" is used differently from how it is in everyday language. In science, **work** is the amount of effort spent when a force causes an object to move a distance. This means that when you kick a soccer ball, work is done on the ball since the force of your foot moved the ball a distance. When you write notes, you apply a force to the pen to move it across the page; you are doing work. What about holding that poster against the wall without moving? You are definitely applying a force, but since the poster is not moving a distance, no work is done on the poster.

B10 *Starting Point* Skills A C

What Is Work?

For each of the photographs in Figure 4.13, use the scientific definition of "work" to decide if work is being done on the object. Justify your answer to a partner. Would people who do not know the scientific definition consider any of these photographs as being "work"?

(a)

(b)

(c)

Figure 4.13 (a) Shooting a basketball, (b) holding a backpack, (c) pulling a sled

B11 *During Reading*

Thinking Literacy

Making Connections

Good readers stay engaged with the text they are reading by making meaningful connections to themselves, to the world, and to other texts. These connections are often coded as text to self (T–S), text to world (T–W) and text to text (T–T). As you read this section, record and code the connections you make. Which connection helps you understand what you are reading best?

Work and Energy

At the end of a long run in your PE class, you might feel as if you have little energy left. At home we turn off the lights or turn down the heat to save energy. Most people are familiar with the word "energy," but what does this word mean? In science, **energy** is defined as the ability to do work. The metric unit for energy is the joule (J), named after James Joule (1818–1889). Work is done when a force causes an object to move. Therefore, energy is the ability to apply a force and move an object. The bowling ball in Figure 4.14 applies a force to the pins and moves them a distance while knocking them down. Since the bowling ball did work on the pins, the rolling bowling ball had energy.

To knock all the pins down, the bowling ball does not have to hit every pin. When the bowling ball does work on the first pin that it strikes, it transfers some of its energy to that pin. The first pin now has energy to knock down another pin. When work is done, energy is transferred from one object to another or from one form of energy to another form of energy.

During any transfer of energy, the total amount of energy remains constant. This means that you cannot create energy, nor can you destroy energy. You can only transfer the energy from one object to another or transform the energy from one form to another. This is called the law of conservation of energy.

Figure 4.14 The energy of the bowling ball does work on the pins that the ball hits.

Forms of Energy

The various forms of energy can be classified into two categories: kinetic energy and potential energy. The bowling ball was able to do work because it was moving. A stationary bowling ball cannot knock down the pins. When an object is moving, the energy it has is called **kinetic energy**. Sometimes the motion is hard to detect. For example, electricity, thermal energy, and sound are forms of kinetic energy since the particles involved in each of these energies are in motion.

In earlier grades, you learned that all matter is made of tiny particles. All these particles are in motion all the time, so they have kinetic energy. Thermal energy is the total amount of all the kinetic energy of all the particles in an object or substance. When this energy transfers to another object or substance, it is called heat.

Energy does not always involve motion. An object can store its energy to do work later. Any energy that is stored is called **potential energy**.

You are able to do work because of the chemical potential energy in the food you eat. As plants and animals grow, they store chemical energy, and they convert it into other forms of energy when they need to. Gasoline and batteries also store chemical potential energy. A bow stores elastic energy until it is released (Figure 4.15).

Figure 4.16 shows a heavy rock directly above a tent peg stuck in the ground. When the rock is dropped, it will apply a force to the peg and move it a distance into the ground. Since the rock can do work on the tent peg if it is dropped, the stationary rock held above the tent peg has potential energy. The potential energy of an object that is able to fall is called **gravitational potential energy**.

WORDS MATTER

The term "kinetic" comes from the Greek word *kinema*, which means motion. Other words with this origin are kinesiology and cinema.

Figure 4.15 In this position, the bow has potential energy.

Figure 4.16 An object that can fall has gravitational potential energy.

Work Produces a Change in Energy

According to our definition of potential energy, a backpack at rest on the floor has no gravitational potential energy since it cannot fall. When you lift the backpack, you are doing work since you are applying a force over a distance, as shown in Figure 4.17. As you do this work on the backpack, the backpack now has the ability to fall. Therefore, the work done on the backpack caused a change in the backpack's gravitational potential energy. Similarly, when you pluck a guitar string, some of the work done on the string is changed into sound energy. In all situations, whenever work is done on an object, there is a change in the object's energy.

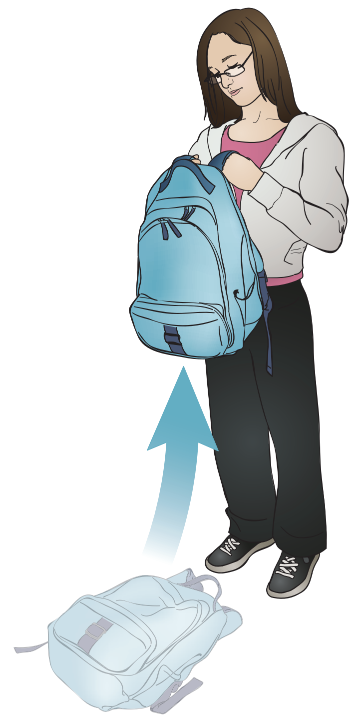


Figure 4.17 When you do work by lifting the backpack, the backpack gains gravitational potential energy.

Work Done by Friction

As mentioned earlier, energy is neither destroyed nor created. Energy can only be transferred from one object to another or transformed from one form of energy to another. When friction does work on an object, some of the object's energy is transformed into thermal energy. An increase in thermal energy makes an object warmer. Thermal energy is the total energy of the moving particles in a substance.

A person running the bases in a baseball game has kinetic energy. While sliding into a base, the player loses that kinetic energy when stopping (Figure 4.18). Since in any situation, energy cannot be lost, where does the player's kinetic energy go? The work done by the friction force transforms most of the kinetic energy into thermal energy. The part of the person's body sliding across the ground gets warmer. This is the same as warming your hands by rubbing them together: the kinetic energy is transformed into thermal energy.

In this unit, you are investigating how mechanical systems use forces to transfer energy. It is important to realize that all mechanical systems include frictional forces. As energy is transferred by a mechanical system, some amount of thermal energy is always produced.

Figure 4.18 Work done by friction to stop the runner produces thermal energy.

Calculating Work

Since doing work changes an object's energy, then work must be measured in the same units as energy, which is the joule (J). Our definition of work can be used to derive an equation needed to calculate the work done on an object. The amount of work done depends on the amount of force exerted and the distance over which the force is applied. When the force causes the object to move in the same direction as the force, the amount of work done can be calculated as follows:

$$(\text{Work in joules}) = (\text{Force in newtons}) \times (\text{distance in metres})$$

This same equation can be written using symbols.

$$W = Fd$$

For example, suppose Jennifer pushes a box with a force of 150 N and the box moves 3.0 m. How much work does Jennifer do on the box?

$$\begin{aligned} W &= Fd \\ &= (150\ \text{N})(3.0\ \text{m}) \\ &= 450\ \text{J} \end{aligned}$$

Jennifer does 450 J of work on the box.

If this box has a mass of 25 kg, how much work will it take her to lift it from the floor to 2.0 m in the air? We still use the equation $W = Fd$, but first we need to find the force needed to lift the box. In Section 4.1, we learned that the force of gravity is given by $F_g = mg$. To lift the box at a constant speed, you have to exert a force equal to its weight.

The force exerted on the box can be calculated as:

$$\begin{aligned} F_g &= mg \\ &= (25\ \text{kg})(9.8\ \text{N/kg}) \\ &= 245\ \text{N} \end{aligned}$$

Therefore, the amount of work done by this force is:

$$\begin{aligned} W &= Fd \\ &= (245\ \text{N})(2.0\ \text{m}) \\ &= 490\ \text{J} \end{aligned}$$

Suggested Activity
B13 Quick Lab on page 111

Take It Further

All devices transfer or transform energy. For example, a flashlight is a device that transforms the chemical energy stored in the battery into light energy and thermal energy. Choose a simple device and describe the energy transformations that take place when that device is used. Begin your search at ScienceSource.

B12 Learning Checkpoint

Calculating Work

Use $W = Fd$ to solve the following questions.

1. Simon lifts a rock 1.5 m by applying a force of 20 N. How much work does Simon do on the rock?
2. Gravity pulls an apple 4.0 m to the ground with a force of 2.0 N. How much work does gravity do on the apple?
3. Jasjot does 450 J of work on an object by pushing the object 15 m at a constant speed. How much force does Jasjot exert on the object?

B13 Quick Lab

How Much Work Does It Take?

In order to calculate the work done on an object, we first need to know the amount of force needed to move the object a measured distance.

Purpose

To determine the amount of work, in joules, needed to move various objects in your classroom

Materials & Equipment

- spring scales
- various objects
- metre stick

Procedure

1. Copy Table 4.4 into your notebook.

Table 4.4

Object	Type of Motion (e.g., lifting, sliding)	Distance (m)	Force (N)	Work (J)

2. Choose four objects that you can move in a straight line by lifting, sliding, or opening. Record these objects in your data table.
3. Indicate the desired motion of each of these objects in your data table. Include the distance you plan to move the object.
4. Keeping the spring scale parallel to the motion of the object, measure the force exerted while moving each object the specified distance. Be sure to pull the object with a slow, constant speed. Record these force values in your data table.
5. Use the formula $W = Fd$ to calculate the work required to move each of your objects.

Questions

6. Which of your four object motions required the most work? The least work? Why?
7. Explain why it was important to pull with a constant speed. How would the force on the spring scale change if you did not pull at a constant speed?
8. Choose one of your objects. Describe the form(s) of energy that were changed as a result of the work being done on that object.

4.2 CHECK and REFLECT

Key Concept Review

1. What is the scientific definition of "work"?

2. What is the definition of "energy"?

3. Classify each of the following as examples of kinetic or potential energy.
   (a) A car is driving along a level road.
   (b) An elastic band is stretched to twice its normal length.
   (c) A book is at rest on the top shelf of a bookcase.
   (d) A lightning bolt produces thunder that travels at 1250 km/h.

4. When you do work to lift an object, what form of energy does the object gain?

5. When frictional forces do work on an object or mechanical system, what form of energy is always produced?

6. Michelle pushes on a wall with a force of 45 N. Explain why Michelle is doing no work on the wall.

Connect Your Understanding

7. Calculate the work done in each of the following situations.
   (a) A horse pulls a wagon with a force of 1200 N and moves it 15 m.
   (b) A cable lifts an elevator 16 m by using a cable with a tension force of 2500 N.

8. (a) How much work is required to lift a 35-kg object from the ground 3.0 m into the air?
   (b) How much gravitational potential energy did this object gain?

Practise Your Skills

9. Three different books are lifted from the ground and placed on separate shelves of a bookcase. The force required to lift each book and the height of its shelf are recorded in the data table shown here. Which book required the most work to move?

Book	Force (N)	Height of Shelf (m)
1	22.0	0.50
2	9.0	1.4
3	3.0	2.1

For more questions, go to ScienceSource.

B14 *Thinking about Science, Technology, and Society*

STSE

Giving Society a Lift

The main idea for this chapter is "mechanical systems use forces to transfer energy." This means that mechanical systems do work to transfer energy. For example, an elevator is a mechanical system that does work to give objects gravitational potential energy. The passenger safety elevator was invented about 150 years ago.

Discuss with a group how the elevator has affected how people live. Create a word web displaying your ideas.

4.3 Mechanical Advantage

Here is a summary of what you will learn in this section:

- A machine is a mechanical system that reduces the force required to accomplish work.
- Machines make work easier by increasing the force, increasing the distance, or changing the direction of the force.
- The force applied to the machine is called the input force, and the force applied by the machine is called the output force.
- The amount by which a machine can multiply an input force is called mechanical advantage.
- Mechanical advantage can be calculated by using the equation $MA = F_{out}/F_{in}$.

When you think of a machine, chances are that you imagine something complex like a car or a bicycle. However, machines can be as simple as a wrench or a screwdriver. A **machine** is any mechanical system that reduces the force required to accomplish work. Removing a tight nut from a bolt using only your fingers is almost impossible since you cannot apply enough force. A wrench multiplies the amount of force that you can apply with your fingers in order to remove the nut (Figure 4.19).

Similarly, a ramp makes it easier to raise a mass a vertical distance. In this section, you will learn how machines make work easier.

Figure 4.19 A wrench makes it easier to remove a nut from a bolt.

B15 *Starting Point* Skills P C

Everyday Machines

A machine is any mechanical system that reduces the force needed to do work. For example, a car jack allows you to lift a car that you would not be able to lift without the jack. Work with a partner and make a list of as many machines as you can think of. Compare your list with those of two other groups and add any machines that are different from the ones on your original list. Keep this list for the next activity.

Figure 4.20 Stairs are an example of a machine that makes work easier.

Functions of Machines

To move from the ground floor of a building to the second floor requires work. Usually this work is done by climbing stairs between the levels. Suppose that all the stairs were removed and replaced by a vertical rope (Figure 4.20). Most people would not be able to provide enough force to climb the rope to the next level. Stairs, therefore, are a machine that allows people to do the work more easily.

Machines make work easier in three ways:

- by increasing the force that can be applied to an object
- by increasing the distance over which the force is applied
- by changing the direction of a force

Figure 4.21 The force that the jaws apply to the nut is greater than the force that the person applies to the handles.

Increasing the Force

It is almost impossible to crack a hard nut with your bare hands. A nutcracker is a machine that increases the applied force (Figure 4.21). When you apply a force to the handles, the jaws of the nutcracker apply a greater force on the nut.

However, the distance that you move each handle is greater than the distance that each jaw moves. Remember from the last section that work is the product of force and distance. When you work on the handles, you apply a small force over a large distance. The jaws of the nutcracker apply a large force over a small distance. However, the *work* done by the jaws of the nutcracker is no greater than the work done by you when you squeeze the handles. This is true for all mechanical systems.

Figure 4.22 The length of the ramp is greater than the height of the truck. By using a ramp to do the work over a longer distance, the person uses less force.

Increasing Distance

The ramp in Figure 4.22 allows the cart to be loaded into the truck with less force than if it were lifted straight up. Regardless of how the cart is loaded, the cart in the truck has gained gravitational potential energy since it is now above the road. This means that work was done to move the cart into the truck.

Lifting the cart straight up, without a ramp, requires a large force over a small distance (the height). When you use a ramp, the distance that the cart is moved increases and thus the force applied decreases.

Changing Direction

Some machines change the direction of the force you apply. The pulley used at the top of a flagpole is one example, as shown in Figure 4.23. When the soldier applies a downward force on the rope, an upward force is exerted on the flag.

Figure 4.23 A flag can be lifted upwards by applying a downward force on the rope.

Input and Output Forces

Whenever a machine is used to do work, two forces are always involved. When you exert a force on the machine, the machine exerts a force on the object. For example, suppose you need to lift a car using a jack, as shown in Figure 4.24. When you apply a force to the handle of the jack, the jack applies a force to the car. The force that is applied to the machine is called the **input force**, symbolized by F_{in}. The force that the machine applies to the object is called the **output force**, symbolized by F_{out}. In the case of our car jack, the input force is the person pushing on the handle, and the output force is the jack pushing up the car.

The input force (F_{in}) is defined as the force exerted on the machine. The output force (F_{out}) is defined as either the force that the machine applies to the object or the force required to move the object without using a machine.

The input force is sometimes called the effort force, and the output force is sometimes called the load force.

Figure 4.24 The input force, F_{in}, and output force, F_{out}, using a car jack

B16 *Learning Checkpoint*

Describing Machine Forces

Copy Table 4.5 into your notebook. Using the list of machines from Activity B15, choose any 10 machines and record them in your data table. Write a title for your table.

For each machine, place an X in the column that you think best describes the function of that machine. For each machine, describe the input and output forces of that machine. An example has been done for you.

Table 4.5

Machine	Function			Input Force	Output Force
	Increase the Force	Increase the Distance	Change Force Direction		
Car jack	X		X	Person pushing on handle	Jack pushing up the car

Mechanical Advantage

Machines such as the nutcracker, ramp, and car jack make work easier because the output force is greater than the input force. The amount by which a machine can multiply an input force is called its **mechanical advantage**. Therefore, the ratio of the output force (F_{out}) to the input force (F_{in}) determines the machine's mechanical advantage.

Since mechanical advantage is the ratio of two forces, measured in newtons, mechanical advantage has no scientific units. You can calculate the mechanical advantage (MA) by using the following equation:

$$\text{Mechanical advantage} = \frac{\text{output force in newtons}}{\text{input force in newtons}}$$

$$MA = \frac{F_{out}}{F_{in}}$$

When jacking up a car, Wei pushes with a force of 250 N on the handle of a jack and the jack applies a force of 3000 N to the car. What is the mechanical advantage of this car jack?

Take It Further

Machines that can lift or move heavy objects usually have a very large mechanical advantage. Tractors and bulldozers are examples of these types of machine. Choose a machine and investigate the maximum mechanical advantage of that machine. Begin your search at ScienceSource.

$$MA = \frac{F_{out}}{F_{in}}$$

$$= \frac{(3000\ N)}{(250\ N)}$$

$$= 12$$

The jack has a mechanical advantage of 12. This means that the jack will output 12 times the amount of force that Wei inputs.

Suppose that Jason and his wheelchair have a total weight of 910 N (Figure 4.25). A force of 130 N is required to push Jason up the ramp. In this example, we think of the output force as the force required to move the object without the ramp. Lifting Jason and the wheelchair up without the ramp would require a force of 910 N. Now we use our equation to calculate mechanical advantage.

Figure 4.25 The ramp has a mechanical advantage greater than 1 since the force needed to push the wheelchair up the ramp is less than the force needed to lift the wheelchair straight up.

$$MA = \frac{F_{out}}{F_{in}}$$

$$= \frac{(910\ N)}{(130\ N)}$$

$$= 7$$

The ramp has a mechanical advantage of 7.

Mechanical Advantage of 1

Not only can a machine multiply the input force and increase the distance over which the force is applied, but a machine can also change the direction of the force. Figure 4.26 shows an object attached to a rope that passes over a fixed pulley. If you pull down on the rope with a force, the same amount of force is applied to the object.

A fixed pulley is a machine that does only one thing: it changes the direction of the force. The mechanical advantage of this machine is 1 since the input and output force are the same size. Machines that have a mechanical advantage of 1 only change the direction between the input and the output forces. These machines do not make the work easier but are instead used for tasks in which the direction of the force must change.

Suggested Activity
B19 Quick Lab on page 120

Figure 4.26 Machines that have a mechanical advantage of 1 only change the direction between the input and the output forces.

Ideal Mechanical Advantage

In a real machine, some of the work done by the input force is converted to thermal energy by the friction in the machine. Because of this, the work done by the output force is less than the work done by the input force. An ideal machine has no friction, and therefore no energy is converted to thermal energy. The mechanical advantage of a machine that has no friction is called the **ideal mechanical advantage** (IMA). The ideal mechanical advantage can be calculated by finding the ratio between the distance over which the input force is exerted on the machine (d_{in}) and the distance over which the output force is exerted on the object (d_{out}).

Suggested Activity
B20 Design a Lab on page 121

Ideal mechanical advantage can be calculated as follows:

$$\text{Ideal mechanical advantage} = \frac{\text{input distance}}{\text{output distance}}$$

$$\text{IMA} = \frac{d_{in}}{d_{out}}$$

Suppose Padma uses a hammer to pull a nail, as shown in Figure 4.27. If she moves the handle of the hammer 30 cm and the nail moves 5.0 cm, what is the ideal mechanical advantage of the hammer?

Figure 4.27 The ideal mechanical advantage of the hammer can be determined by comparing the distance the handle moves to the distance the nail moves.

$$\text{IMA} = \frac{d_{in}}{d_{out}}$$

$$= \frac{(30\text{ cm})}{(5.0\text{ cm})}$$

$$= 6.0$$

The ideal mechanical advantage of the hammer is 6.0.

Even though no real machines have zero friction, certain machines have such a small amount of friction that the ideal mechanical advantage is very similar to the real mechanical advantage. Machines like a hammer or a screwdriver have no sliding parts and therefore have almost no friction. The IMA can be close to the MA for machines such as these.

Ideal Mechanical Advantage of Less Than 1

Sometimes, the IMA is less than 1 and the output distance is greater than the input distance. This usually means that the speed at the output is higher than the speed at the input. Examples of machines with an IMA less than 1 are hockey sticks, baseball bats, and garden rakes. In each of these machines, the distance moved by the input force is less than the distance moved by the output force (Figure 4.28). When an increase in speed of motion is required, an IMA of less than 1 is sometimes necessary.

Figure 4.28 When you shoot with a hockey stick, the distance moved by the hands is less than the distance moved by the stick's blade. Thus, the speed of the blade (output) is greater than the speed of the input (hands).

B17 *Learning Checkpoint*

Mechanical Advantage

1. Laura pushes on the pedals of her bike with a force of 320 N. If the bike has an output force of 640 N, what is the mechanical advantage of this bike?
2. Laura squeezes the hand brakes of her bicycle with a force of 60 N. If the brake pads push on the wheel with a force of 300 N, what is the mechanical advantage of this bike's brake system?
3. The handle of a car jack is moved 75 cm and the car is lifted 2.5 cm. What is the ideal mechanical advantage of this car jack?

B18 *Learning Checkpoint*

Human Mechanical Advantage

If you did Activity B3, you lifted masses at various locations on your arm. When you used your elbow joint as a hinge, your muscles were the input force and the weight of the object was your output force (Figure 4.29). Since the mass was the same regardless of its location on your arm, the output force provided by your arm was always the same.

1. Explain what happened to the mechanical advantage of your arm as the weight was moved along your arm.
2. Do you think the mechanical advantage of your arm was ever greater than 1? Explain.

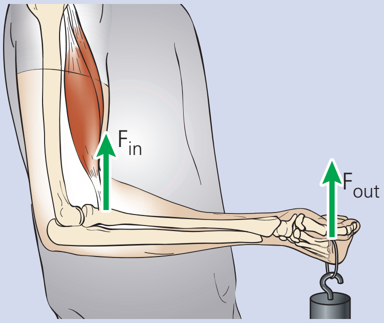


Figure 4.29

B19 *Quick Lab*

Calculating Mechanical Advantage

The mechanical advantage of a machine can be determined by calculating the ratio of the output force to the input force ($MA = F_{out} / F_{in}$). If the output force (F_{out}) is required to slowly lift an object, then the output force is equal to the weight of the object ($F_g = mg$).

Purpose

To determine the mechanical advantage of a metre stick, hinged at different locations and used to lift a mass

Materials & Equipment

- spring scale
- hooked masses
- ring stand or support
- metre stick
- string

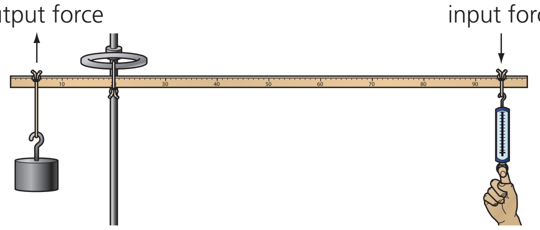


Figure 4.30

Procedure

1. Copy Table 4.6 into your notebook.

Table 4.6 Mechanical Advantage of a Simple Machine

Hinge Location (cm)	Output Force (N)	Input Force (N)	Mechanical Advantage
20			
30			
40			
50			
60			
70			

2. Suspend the metre stick from the support stand using a piece of string attached to the 20-cm location of your metre stick. This location is called the hinge location.
3. Attach your hooked mass to the 5.0-cm location of your metre stick using a second piece of string (Figure 4.30).
4. Using a spring scale attached to the 95-cm location of your metre stick, pull the metre stick until it is parallel to the ground. Record this force as the input force.
5. Record the output force provided by the metre stick. The output force is the force required to lift the hooked mass ($F_g = mg$).
6. Repeat steps 3–5 for the hinge locations in your data table.
7. Calculate the mechanical advantage of the metre stick at each of the hinge locations. Record these values in your data table.

Questions

8. As the distance from the output force to the hinge increased, what happened to the value of the mechanical advantage?
9. When the hinge was at the 70-cm location, the mechanical advantage has a value of less than 1. In a short paragraph, explain what a mechanical advantage less than 1 means in terms of input and output forces.
10. When the mechanical advantage is greater than 1, the distance moved by the output force is less than the distance moved by the input force. How do these distances compare when the mechanical advantage is less than 1?

B20 *Design a Lab* Toolkit 2

SKILLS YOU WILL USE
- Initiating and planning
- Communicating

My Bicycle's Mechanical Advantage

A bicycle is a mechanical system that transfers the force that you push on the pedals to a force on the ground provided by the wheel rims.

Multigear bikes can change the mechanical advantage depending on the gear. Gears are devices that change the speed, direction, or force of a transmitted motion. The mechanical advantage of a bicycle can be calculated by measuring the force on the pedals and the force on the wheel (Figure 4.31). Ideal mechanical advantage can be calculated by measuring the distance the pedal travels and the distance the bicycle travels.

Question

What are the mechanical advantage and ideal mechanical advantage of a bicycle?

Design and Conduct Your Investigation

1. Decide what materials you will need in order to record the measurements you need to be able to calculate both mechanical advantage and ideal mechanical advantage.
2. Plan your procedure. Think about these questions.
   (a) How will you measure the force on both the pedals and the wheel rim at the same time?
   (b) Since the pedals do not move in a straight line, what method will you use to measure the distance the pedals travel?
   (c) What steps will you follow to collect the data you need?
   (d) How will you record your results?
3. Write up your procedure. Be sure to show it to your teacher before going any further.
4. Carry out your experiment.
5. Share and compare your experimental plan and values with your classmates' plans and values. Did any other group plan their experiment exactly like yours? Similarly to yours? Completely different from yours? How did your bike's mechanical advantage compare to its ideal mechanical advantage? If the values were different, give an explanation.
6. Present your findings to the class or in a form suggested by your teacher.

Figure 4.31

4.3 CHECK and REFLECT

Key Concept Review

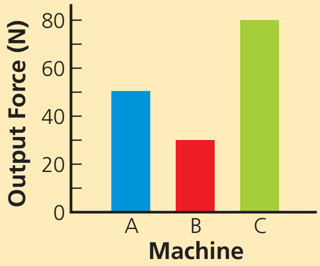
1. Explain what is meant by the statement "a machine makes work easier."
2. What concept is represented by the ratio of the output force to the input force?
3. Jill applies a force of 15 N to a wrench. If the wrench applies a force of 150 N to a bolt, which of these values is the input force and which is the output force?
4. A pulley has a mechanical advantage of 1. What does this tell you about the size and direction of the input and output forces?
5. Use the concept of energy to explain why ideal mechanical advantage is not the same as mechanical advantage for real machines.

Connect Your Understanding

6. What is the mechanical advantage of a machine that exerts a force of 160 N on an object when a person exerts a force of 20 N on the machine?
7. A bicycle moves forward 4.0 m when the pedals are rotated through a distance of 1.0 m. What is the IMA of this bicycle?

Practise Your Skills

8. Ravi applies the same force to three different machines. The output force of each of these machines is shown here. List the three machines in order of highest to lowest mechanical advantage.



For more questions, go to ScienceSource.

B21 *Thinking about Science, Technology, and Society*

Can Opener

Can you imagine opening a can of soup without a can opener? A can opener is a mechanism designed to make the task of opening a can easier.

What to Do

1. Make a sketch of a manual can opener.
2. Identify the components of the can opener and label these parts on your sketch.
3. State the form and function of each labelled part.

Consider This

4. Most mechanisms are designed to meet a need. How well does your can opener address people's needs?
5. If every family had to destroy its can openers, describe the short- and long-term effects.
6. Describe possible environmental effects on the manufacturing, use, and disposal of your can opener.

Science and Technology in Your World

Artificial Limbs

Artificial limbs or prostheses (singular: prosthesis) have been in use for more than 2300 years. An artificial leg was found that was made from copper and wood and dated from 300 B.C.E. A prosthesis is designed to replace a limb that is missing due to injury or disease, or from birth.

The last 50 years have seen the greatest advances in artificial limbs. Lightweight plastics and carbon fibres make the limb easier to move. The most exciting development is myoelectricity, which means that electric signals from the person's muscles can move the artificial limb. Sensors attached to the muscles transfer the muscle motion into electrical impulses. These electrical signals are sent to the areas of the prosthesis where motion is required.

Regardless of the technology used, an artificial limb is a machine that transfers forces. Interior cables pull hinged levers or use hydraulics. Designers of these high-tech devices are highly trained biomedical engineers. They must understand force, work, energy, and machines.

Prosthesis technology is now so advanced that some artificial limbs can perform better than a natural limb. Oscar Pistorius is a double-amputee sprinter who uses special composite prosthetic blades. He has run in many international competitions.

Questions

1. What technologies have created the greatest changes in prosthesis development?
2. What are two methods used to transfer forces in a prosthesis?
3. Do you think that athletes such as Oscar Pistorius should be allowed to compete against other athletes at the Olympics? In a short paragraph, give reasons for your answer.

Figure 4.32 In the 16th century, artificial limbs had moving parts that were controlled by straps attached to the body.

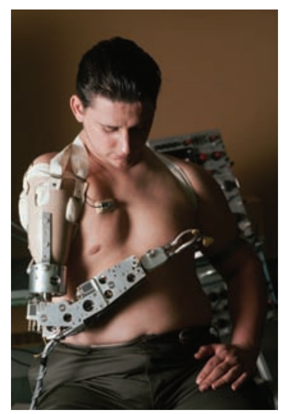


Figure 4.33 Each motion of the artificial limb is the result of the transfer of forces.

Figure 4.34 Oscar Pistorius, the "Blade Runner," with his carbon-fibre feet

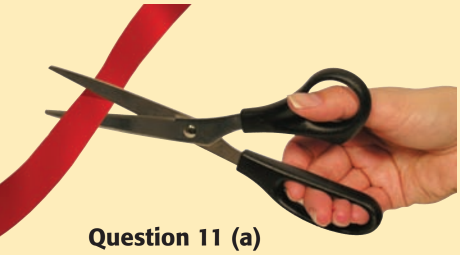
4.0 Chapter Review

Assess Your Learning

After Reading — Thinking Literacy

Reflect and Evaluate

Based on your learning, add and modify the mind map you began on page 95. How and where would you fit in the following words: machine, mass, weight, friction, and ideal mechanical advantage? Draw lines and arrows between the words on your mind map in a way that makes sense to you. Explain your mind map to a partner. How has the strategy of making connections helped you to understand this chapter better?



Question 11 (a)

Question 11 (b)

Key Concept Review

1. A curling rock slides to a stop due to the force of friction. Is the force of friction a contact force or a force at a distance? (k)
2. Dan has a mass of 55 kg on Earth. What is his mass on a planet that has twice Earth's gravity? (k)
3. Explain how it is possible to do no work on an object even though you have applied a force to that object. (k)
4. For each of the following situations, state if the object has potential energy or kinetic energy. (k)

   (a) a bowling ball rolling down the alley

   (b) a book sitting on the top shelf of a bookcase
5. State the three functions of machines and give an example of a machine for each function. (k)
6. For a given machine, explain why the MA is usually less than the IMA. (k)
7. If you exert an input force over a greater distance than the distance exerted by the output force, for an ideal machine compare the sizes of the input and output forces. (k)
8. What concept is represented by the ratio of the input distance to the output distance? (k)

Connect Your Understanding

9. Suzy pushes against a brick wall with a force of 900 N for 1 minute. Her friend comments that she did no work during that minute. Is her friend correct? Explain. (a)
10. Ahmed inputs 250 J of work on a machine. Explain why that machine has an output of only 200 J of work. (a)
11. Make a sketch of each machine in the two photographs and label the input force and the output force in each. (t)
12. In a short paragraph, describe how you would determine the amount of work needed to pull a toboggan the length of a football field. Be sure to include the equipment list and describe the measurements that you will take. (a)

ACHIEVEMENT CHART CATEGORIES

(k) Knowledge and understanding (t) Thinking and investigation (c) Communication (a) Application

Practise Your Skills

13. What is the weight of a 3.0-kg mass placed on a spring scale in your classroom?

14. Calculate the amount of work done in each of the following situations.

(a) A person lifts a 250-N child straight up 1.2 m.

(b) A horse pulls a sled 12 m using a force of 2000 N.

15. A machine is able to lift a 50-kg mass when a 49-N force is applied to the machine. What is the mechanical advantage of this machine?

16. The handle of a car jack is moved 150 cm in order to lift the car 5.0 cm. What is the ideal mechanical advantage of this car jack?

17. A machine is often designed when the work required to move an object needs a force larger than a person can exert. Your task is to lift a 400-kg boulder from the ground and place it on a platform 3.0 m high.

(a) Make a sketch of a machine (or a combination of machines) that use the force provided by one person to accomplish this task.

(b) Label the input and output force(s) on your sketch.

Unit Task Link

You will design, construct, and test a mechanical system that uses only the energy stored in a spring-bar mousetrap. This system must have a function other than catching mice. Will your design require a mechanical advantage greater than 1 or less than 1? How will your design produce the required mechanical advantage?

B22 *Thinking about Science, Technology, and Society*

Garden Rake versus Leaf Blower

For many people in Ontario, the beauty of autumn becomes the chore of gathering and disposing of the fallen leaves. Not that long ago, the garden rake was the only machine used to gather leaves. Some people now use electric- or gas-powered leaf blowers.

What to Do

1. Draw the following data table so that it fills a full page in your notebook.

	Environmental		Societal	
	Cost	Benefit	Cost	Benefit
Garden rake				
Leaf blower				

Consider This

With some classmates,

2. Brainstorm possible environmental and societal costs and benefits for the garden rake and the leaf blower. Record your results in the table.

3. Discuss why people saw a need for leaf blowers.