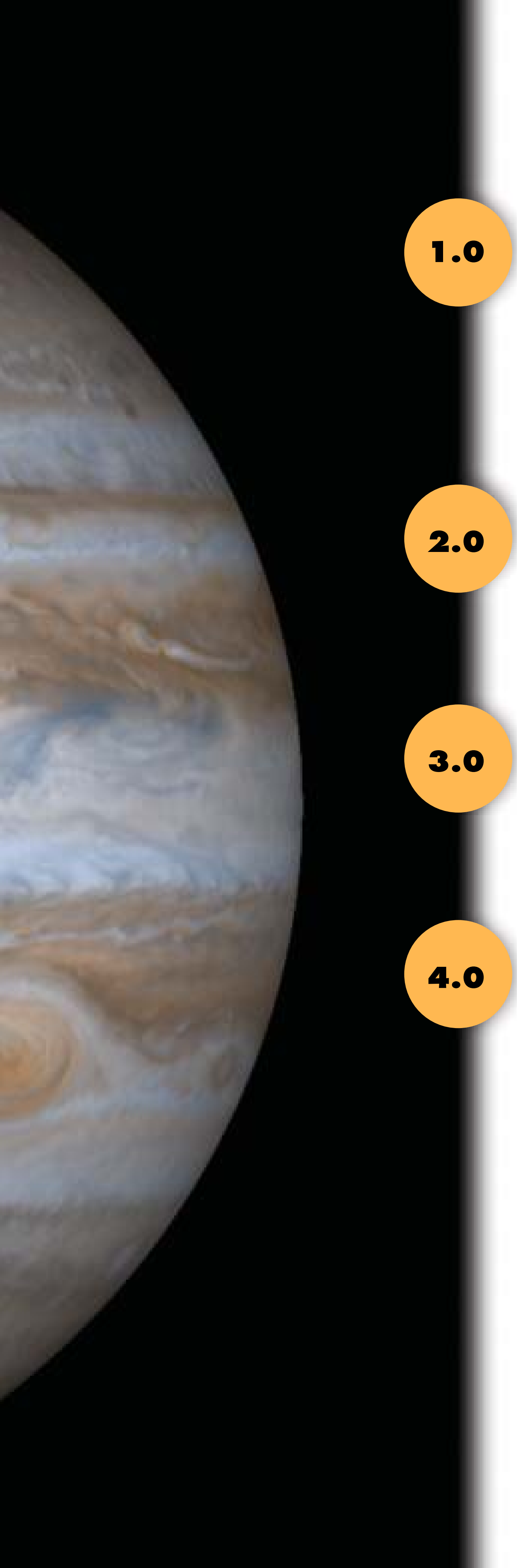
UNIT

E

Space Exploration



In this unit, you will cover the following sections:

1.0

Human understanding of both Earth and space has changed over time.

1.1 Early Views About the Cosmos
1.2 Discovery Through Technology
1.3 The Distribution of Matter in Space
1.4 Our Solar Neighbourhood
1.5 Describing the Position of Objects in Space

2.0

Technological developments are making space exploration possible and offer benefits on Earth.

2.1 Getting There: Technologies for Space Transport
2.2 Surviving There: Technologies for Living in Space
2.3 Using Space Technology to Meet Human Needs on Earth

3.0

Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

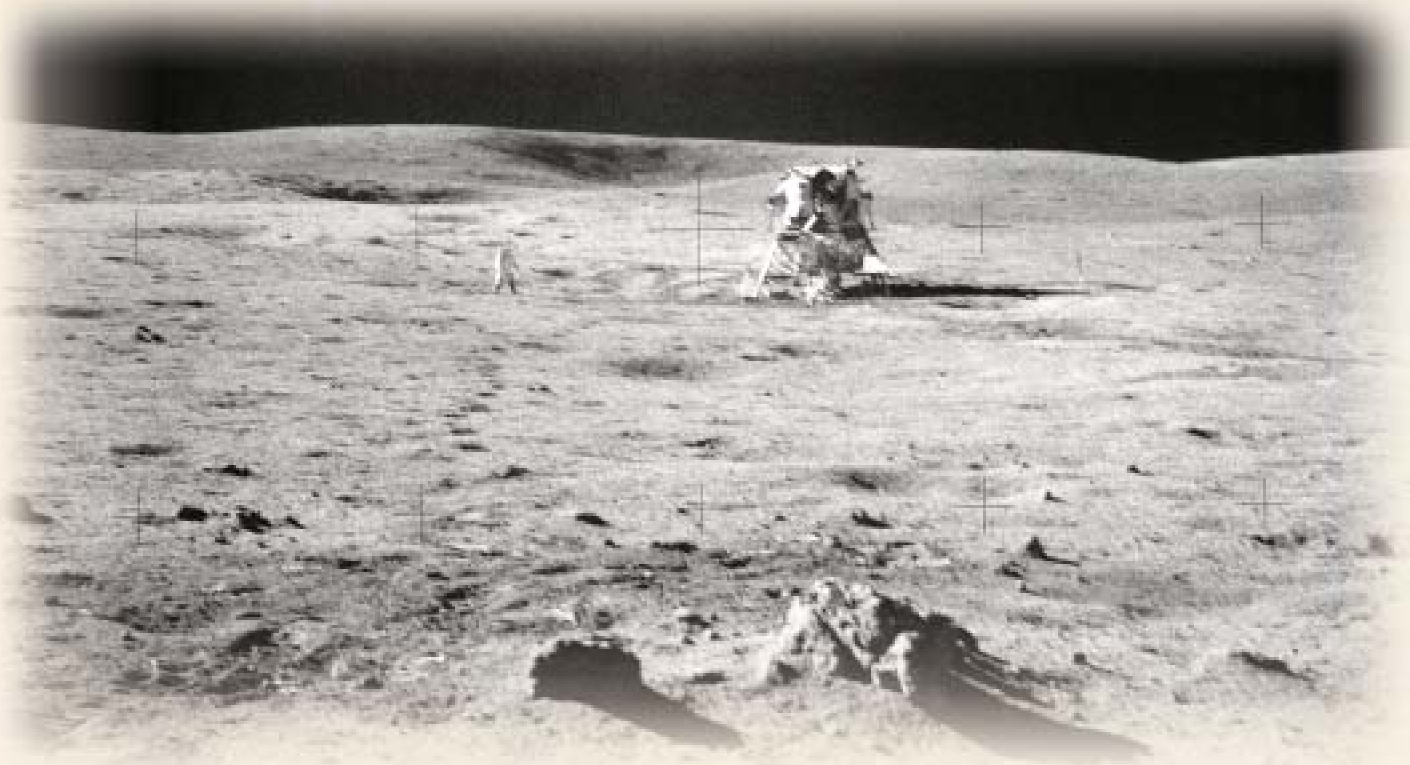
3.1 Using Technology to See the Visible
3.2 Using Technology to See Beyond the Visible
3.3 Using Technology to Interpret Space

4.0

Society and the environment are affected by space exploration and the development of space technologies.

4.1 The Risks and Dangers of Space Exploration
4.2 Canadian Contributions to Space Exploration and Observation
4.3 Issues Related to Space Exploration

Exploring



When humans walked on the Moon for the first time, the world watched.

The first major step in the human journey to explore space occurred on July 20, 1969. That was the date when two U.S. astronauts, Neil Armstrong and Edwin "Buzz" Aldrin, walked on the Moon, becoming the first people to visit a body in the solar system other than Earth. It also marked the first time that people on Earth could look up at the Moon and know that there were people on its surface looking back at them!

SHORT EXCURSION TO THE MOON

It took four days for the lunar module *Eagle* to make the trip from our planet to the Moon's surface. When it touched down, only a few seconds' worth of the budgeted fuel for landing remained. If the process of landing had taken longer, the *Eagle* would have started using up the fuel rationed for getting the spacecraft and its crew home.

The most sophisticated technology of the time was used to carry the astronauts safely to the Moon and back to Earth, a journey that, in total, took a little over eight days. Future journeys into space may take months, even years in travel time, but such is the nature of exploration. Leaving the safety of Earth's atmospheric bubble will always pose one of the ultimate challenges to our ingenuity. That is the reason that humans continue to search, stretching the limits of their imaginations to create the technology that will take us ever farther into space.

GIVE IT A TRY

CRATER PATTERNS ON THE MOON

The surface of the Moon is covered with “impact craters” of every size. These are depressions made when meteoroids (small pieces of rock in space) and asteroids (much larger rocky bodies) strike the ground with a tremendous force. Most meteoroids and asteroids encountering Earth burn up in Earth’s atmosphere and never reach the ground. The Moon does not have an atmosphere and, therefore, any meteroid or asteroid caught in the Moon’s gravity ends up hitting the surface. This activity gives you an idea of how crater patterns are caused by these impacts.

1 Place the trays on a newspaper-covered table or floor area.
2 Pour the flour into the trays to a depth of about 5 cm.
3 Gently sprinkle the cocoa powder over the flour so that a mostly brown layer is visible on the surface.
4 Drop the rocks and marbles from a variety of heights onto the flour-and-cocoa surface. Sketch the different impact patterns left by the dropped “meteors.”
5 Experiment with letting the rocks and marbles hit the surface at an angle. How does this change the impact pattern?

Materials & Equipment

- two large plastic or aluminum trays
- newspaper
- flour (one 3.5-kg bag)
- cocoa powder (about 250 mL)
- rocks or marbles of different sizes

Focus On SCIENCE AND TECHNOLOGY

As you learn in this unit about the advances humans have made in exploring and understanding the nature of space, you will be given many opportunities to solve problems using your knowledge of both science and technology.

Science provides an orderly way of studying and explaining the nature of things. Technology tries to find solutions to practical problems that arise from human needs. As you will discover in working through this unit, there are often many possible solutions to the same technological problem. To guide your reading as you study how science and technology interact and support each other, keep the following questions in mind:

1. **How much do humans know about space?**
2. **What technologies have been developed so that space can be studied?**
3. **How have space technologies contributed to the exploration and use of space, and how have they benefited our life on Earth?**

1.0

Human understanding of both Earth and space has changed over time.

Key Concepts

In this section, you will learn about the following key concepts:

- technologies for space exploration and observation
- reference frames for describing the position and motion of bodies in space
- distribution of matter through space
- composition and characteristics of bodies in space

Learning Outcomes

When you have completed this section, you will be able to:

- identify different perspectives on the nature of Earth and space
- investigate and illustrate the contributions of technological advances to a scientific understanding of space
- describe the distribution of matter in space
- identify evidence for, and describe characteristics of, bodies that make up the solar system and compare their characteristics with Earth's
- describe and apply techniques for determining the position and motion of objects in space
- investigate predictions about the motion, alignment, and collision of bodies in space

Imagine that your teacher brings to class a meteorite that is about the size of a grapefruit. Meteorites are pieces of rocky space debris that hit Earth. Your teacher asks you to study and describe the meteorite's surface. With your unaided eye, you would be able to see many of the object's characteristics, such as its colour, lustre, and texture. With a magnifying glass, you would see even more detail, perhaps the colour and shape of the surface particles.

Now, think how your description would change if you could use a high-powered microscope that greatly magnifies a chip from the meteorite. Details you could never have noticed before would become visible. As a result, your understanding of the meteorite's composition would improve.

In this section, you will learn how human understanding of Earth and the universe has changed over thousands of years, boosted each step of the way by advances in technology. You will also learn that the role of observation in guiding scientific understanding of space remains as important today as it was to early astronomers. Only the capacity to see more is constantly expanding.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Early Views About the Cosmos

Objects in the sky have fascinated humans throughout history. Many of these objects you have certainly seen yourself, such as the Sun, the Moon, stars and constellations, and planets, such as Venus, Mars, and Jupiter. Maybe you have also been fortunate to see an eclipse, a comet, a meteor shower, or the aurora borealis. All of these celestial bodies and events have been watched in wonder for thousands of years. They fuelled the human imagination, marked the passage of time, and foretold the changes in seasons. Early knowledge of them was passed from generation to generation and from culture to culture, often as legends and folklore.

*info***BIT**

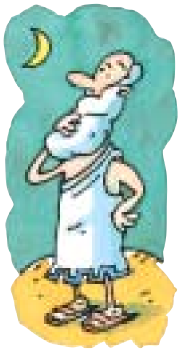
One-Mitt Measure
Inuit in the high arctic traditionally used the width of a mitt held at arm's length to gauge the height of the Sun above the horizon. When the Sun rose to a height of one-mitt width, it meant that seal pups would be born in two lunar cycles.

Figure 1.1 The First Nations peoples of the Pacific Northwest thought the night sky was a pattern on a great blanket overhead. The blanket, they believed, was held up by a spinning "world pole," the bottom of which rested on the chest of a woman underground named Stone Ribs.

GIVE IT A **TRY**

EVOLVING IDEAS ABOUT PLANETARY MOTION

In this subsection, you will be learning how our early understanding of space and Earth's place in it have developed through history.



1. Make a time line that shows when key ideas about space were proposed and who proposed them. Start your time line at 3000 B.C. and add to it as you read through this subsection. End at the heliocentric model of the solar system. For each idea, be sure to include the observations the person made that led to the idea.
2. Compare your time line with that of other students in the class. Add to your time line any ideas you might have missed.
3. Discuss with the class the main technologies that were used by people in developing each key idea on your time line.

Figure 1.2 The origins of England's Stonehenge remain an archeological puzzle.

TRACKING COSMOLOGICAL EVENTS

Two very special annual events for our ancestors were the summer and winter **solstice**. The word "solstice" comes from the Latin *sol* meaning sun, and *stice* meaning stop. In the northern hemisphere, the summer solstice occurs near June 21. It marks the longest period of daylight in the year and represents the start of summer. The winter solstice occurs near December 21. It marks the shortest day of the year and the start of winter. (The conditions are the reverse in the southern hemisphere.)

Prediction of the approach of summer and winter was important to early peoples, and many ancient civilizations built huge monuments to honour their beliefs about the change. While they may have had only the power of the unaided eye, their observations of the position and path of the Sun throughout the year were highly accurate. More than 3500 years ago, for example, a people (possibly the ancient Celts) erected the megaliths of Stonehenge, still standing in southern England. Arranged in concentric circles, the enormous stones mark the summer and winter solstices. Ancient African cultures also set large rock pillars into patterns that could be used to predict the timing of the solstices.

Another phenomenon honoured by early cultures was the **equinox**, one in the spring (about March 21) and one in the fall (about September 22). The word "equinox" comes from the Latin *equi* meaning equal, and *nox* meaning night. At the equinox, day and night are of equal length. The Mayans of Central America built an enormous cylinder-shaped tower at Chichén Itzá in about A.D. 1000 to celebrate the occurrence of the two equinoxes.

The ancient Egyptians built many pyramids and other monuments to align with the seasonal position of certain stars. The entrance passage of Khufu, the Great Pyramid at Giza, once lined up with Thuban (a star in the constellation of Draco). At the time the pyramid was built, starting about 2700 B.C., Thuban was the closest star showing true north. Two thousand years ago, aboriginal peoples of southwestern Alberta used large rocks to build medicine circles in which key rocks aligned with the bright stars that rose in the dawn, such as Aldebaran, Rigel, and Sirius.

Figure 1.3 The designs of the pyramids at Giza, Egypt, and in Chichén Itzá, Mexico, were influenced by celestial observations.

MODELS OF PLANETARY MOTION

For as long as people have been watching the nightly promenade of stars and planets, they have sought ways of explaining the motions they observed. The religions, traditions, myths, and rituals of ancient cultures all reveal different interpretations of how the universe works. Seen from Earth, everything in the sky appears to be in motion. The Sun rises and sets. The Moon, in its ever-changing phases, travels across the sky. Planets shift against a background of stars. Even constellations (groupings of stars) appear to change position in the sky throughout the year. Our ancestors had to make sense of this constant pattern of change by using the science and technology of the day.

Geocentric Model

About 2000 years ago, the Greek philosopher Aristotle proposed a **geocentric**, or Earth-centred, model to explain planetary motion. In the model, he showed Earth at the centre, surrounded by a series of concentric spheres that represented the paths of the Sun, Moon, and five planets known at the time (see Figure 1.4). To explain why the distant stars did not move, Aristotle hypothesized that they were attached firmly to the outermost sphere (what he called the "celestial sphere") where they stayed put as though glued to an immovable ceiling.

Little optical technology is believed to have existed in Greece during the time Aristotle was making his observations about the cosmos. However, he was aided by the mathematics and geometry of Pythagoras and Euclid, which he used to calculate the size and shape of the spheres.

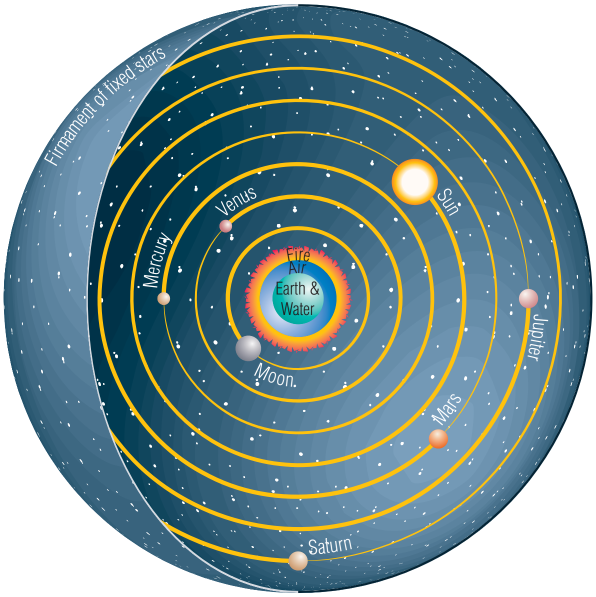


Figure 1.4 Aristotle's geocentric model of our solar system explained much—but not all—about planetary motion. In this model, Earth was the centre of the universe.

The geocentric model allowed early astronomers to forecast such events as the phases of the Moon, but it still could not explain many other observations. For example, why did Mars, Jupiter, and Saturn sometimes seem to loop back opposite to their usual movement across the sky?

reSEARCH

Legends of the Sun

The Sun played a prominent role in the mythology of many ancient cultures. Research the beliefs, ceremonies, and legends that three of the following groups held about the Sun: North American First Nations, Australian Aborigines, Aztecs, Chinese, Egyptians, Greeks, Inuit, Japanese, and Norse. Compare your findings with those of others in the class. Begin your search at www.pearsoned.ca/scienceinaction.

Heliocentric Model

The Earth-centred model of our solar system lasted for almost two thousand years. Then, in 1530, Polish astronomer Nicholas Copernicus proposed a dramatically different model, one that explained planetary motion much more simply than did the complicated geocentric model. Copernicus suggested that the Sun was at the centre and Earth and the other planets revolved in orbits around it. This is called the **heliocentric** model (Figure 1.5).

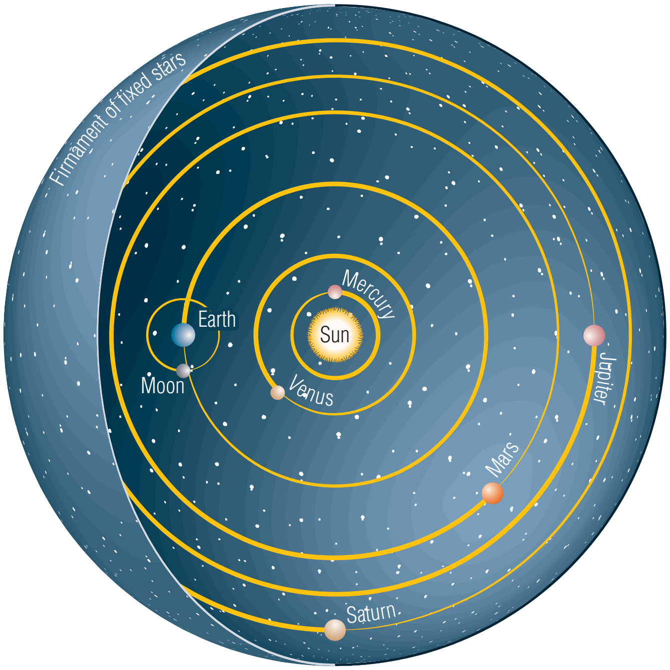


Figure 1.5 The heliocentric model of our solar system put the Sun at the centre of the universe. It was considered, at the time, to be a revolutionary idea.

A little less than 100 years later, a new generation of scientists—with the help of a major technological invention, the telescope—provided solid evidence for Copernicus's theory. Notable among these scientists was the renowned Galileo Galilei of Italy. In the 1600s, using a telescope not much stronger than the standard binoculars you might use today, he was the first person to view mountains on the Moon, a "bump" on either side of Saturn (later found to be the outer edges of the planet's rings), spots on the Sun, moons orbiting Jupiter, and the distinct phases of Venus.

Even though Galileo's discoveries added credibility to the Copernican ideas, the model could still not predict planetary motion very accurately. A German mathematician, Johannes Kepler, came up with the next solution to the puzzle. Using detailed observations of the movement of the planets (observations carefully recorded by the great Danish astronomer, Tycho Brahe), Kepler discovered what was missing from the Copernican ideas. The orbits of the planets, he realized, were **ellipses** and not circles. Today, the Sun-centred model of our solar system is used as a guide when we study other solar systems.

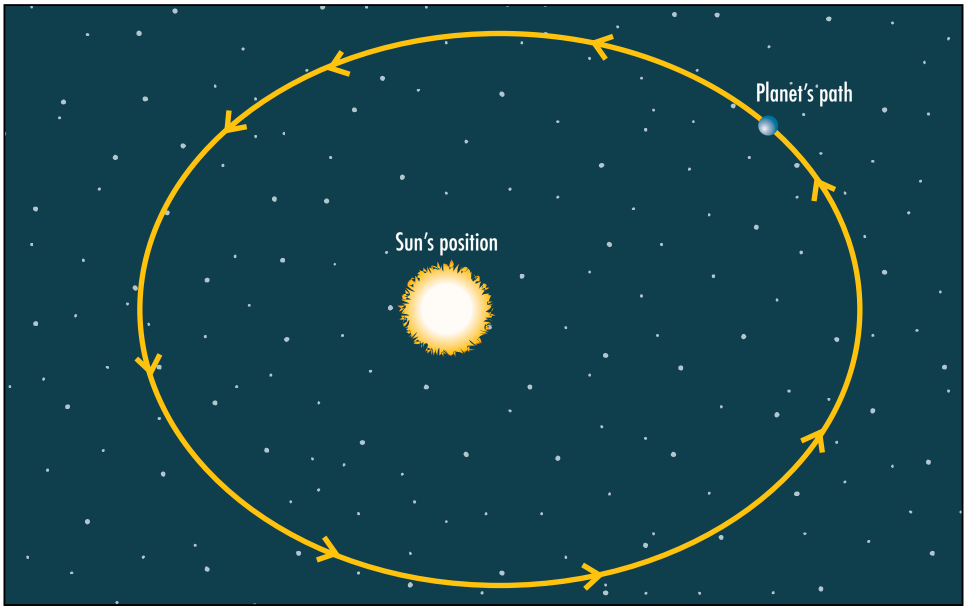


Figure 1.6 Once astronomers realized that planets orbited the Sun in elliptical paths, not circular paths, they were better able to predict planetary motion.

QUICKLAB

ELLIPTICAL LOOPS

Purpose

To draw a series of ellipses and investigate their properties

Procedure

1. Draw a straight line, about 20 cm long, down the middle of the paper. Position the paper on top of the cardboard and set the cardboard on a firm, flat surface such as your desk top.
2. Position the pins 5 cm apart along the drawn line and push the pins through the paper and into the cardboard so they are standing upright.
3. Place the loop of thread around both pins. Then, with the pencil point resting inside the loop, pull gently until the thread is taut and the pencil point is touching the paper (see Figure 1.7).
4. While keeping a slight outward pressure with the pencil against the thread, start drawing a line in a circular motion around the pins. You will see an ellipse (an oval shape) start to form. A circle is formed around one focal point. An ellipse is formed around two focal points.
5. Repeat steps 3 to 5 two more times, once setting the pins closer together and once setting them farther apart. Observe how the ellipse changes.

Questions

6. Describe what happens when the pins are moved different distances apart. How does the position of these focal points change the shape of the ellipse?
7. Imagine that one of the pins is the Sun and the pencil point is a planet. What controls the shape of the elliptical path?
8. What shape would you expect if both pins were at exactly the same point?

Materials & Equipment

- sewing thread (30 cm long), with ends tied to make a loop
- paper (letter-size)
- ruler
- pencil
- cardboard (30 cm by 30 cm)
- 2 straight pins or tacks

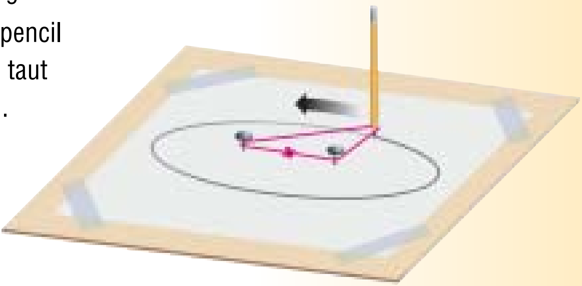


Figure 1.7 Step 3

CHECK AND REFLECT

Key Concept Review

1. Define solstice. What are the significant dates associated with the solstices in the northern hemisphere?
2. What was the ancient monument of Stonehenge believed to be used for?
3. What word is used to describe the times when the length of day equals the length of night? When do these occur?
4. List and describe three monuments built by ancient people to honour celestial bodies.

Connect Your Understanding

5. What did the summer and winter solstices indicate to ancient people?
6. Explain the main difference between the heliocentric model of the solar system and the geocentric model.
7. Why was the change from a geocentric model to a heliocentric model considered such a revolutionary idea?

Extend Your Understanding

8. Johannes Kepler used hundreds of years' worth of historical data collected by many astronomers (notably Tycho Brahe) and his own precise measurements to modify the Copernican model. How did the change proposed by Kepler make the model more realistic?
9. The velocity at which a planet travels does not remain constant throughout its orbit. As it gets closer to the Sun in its orbit, a planet tends to speed up a little. Why do you think this occurs? Use Figure 1.6 to assist you with answering this question.

Figure 1.8 The Caracol, a 3000-year-old Mayan observatory located at Chichén Itzá on the Yucatán Peninsula in Mexico

1.2 Discovery Through Technology

Step by step, our understanding of space and Earth's place in it has progressed, thanks in large part to the improvement of the tools available to observe, record, measure, and analyze what we see. This process of discovery boosted by technological advance is going on all the time.

Figure 1.9 State-of-the-art technology today will be thought of as old-fashioned to the next generation of science students.

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Fasten Your Seat Belts

The Sun lies about 149 599 000 km from Earth. Compared to other distances in the universe, that is not very far. However, if you could fly in a 747 airliner from Earth to the Sun (travelling at about 965 km/h), the flight would last close to 17 years.

***QUICK*LAB**

TELLING SUNDIAL TIME

Purpose

To make a model sundial and plot shadow patterns

Materials & Equipment

- a sheet of polar graph paper (circular graph paper)
- a golf tee
- adhesive tape
- a pencil

Procedure

① Go to an area of your classroom or another room in the school where the Sun is shining in. (If you must leave the classroom to do this activity, be sure to ask your teacher's permission first.)

② Tape the paper on a flat surface in the sunlight. Stand the golf tee upside down in the centre of the graph paper.

③ With your pencil, plot the shadow cast by the golf tee on the graph paper and make a note of the time. Repeat this step at regular intervals during the day.

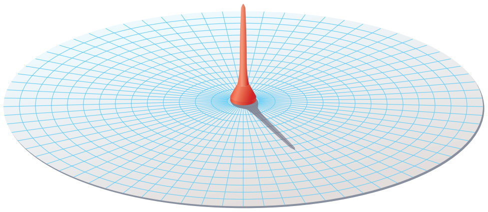

Figure 1.10 Step 2

Questions

4 Describe the pattern you see in the shadow plots you have drawn during the day. Sketch the pattern in your notebook.

5 If you were to repeat this activity every day for a year, would the same pattern result each time? Explain your answer.

THE ASTRONOMER'S TOOLS

Humans are very inventive, and have worked hard over the centuries to develop tools to help them better understand the sky and its mysteries. Sundials, for example, have been used for more than 7000 years to measure the passage of time. Ancient Egyptians invented a device called a merkhet to chart astronomical positions and predict the movement of stars. About the 2nd century A.D., the Egyptian astronomers also designed a tool called a quadrant to measure a star's height above the horizon. Arabian astronomers used the astrolabe for centuries to make accurate charts of star positions. In the 14th century, astronomer Levi ben Gurson invented the cross-staff to measure the angle between the Moon and any given star. With each of these technological innovations, astronomers made new discoveries and gained more knowledge about what they were seeing.

quadrant *astrolabe* *cross-staff* *early telescope*

Figure 1.11 Many early tools were invented to study and predict celestial motion. Sailors and other explorers tested these instruments in their travels to uncharted places of the globe.

Then came the telescope. Invented in the late 16th century, it revolutionized astronomy. Suddenly, astronomers such as Galileo could see more in the night sky than had ever been possible. Telescopes revealed exciting details about Earth's closest planetary neighbours, and showed the existence of other neighbours in our solar system. We learned that the size of what lay beyond Earth was greater than anything we could have imagined.

With each new improvement, the optical telescope pushed astronomy ahead. As our viewing ability got better, the vast distance between objects in space became obvious.

Today, almost 500 years after the telescope's invention, super-powerful optical and radio telescopes operating from Earth, satellites orbiting around Earth, and sophisticated space-based telescopes have shown us the immensity of objects in space and of distances across the universe. (You will learn more about space technologies in Section 3.0.) We have discovered that our Sun is only an average star, lying in a small corner of an average galaxy that is one among billions of other galaxies.

THE IMMENSITY OF DISTANCE AND TIME IN SPACE

If you were asked to measure the size of your school, you probably would not do so using millimetres. Neither would you use centimetres to describe the distance from your school to home. Finding the appropriate unit of measurement is important when describing distances.

In the case of measuring distances in space, not even kilometres are practical to use. To have a practical means of describing such enormous distances, astronomers devised two new units of measure.

Astronomical Units

The **astronomical unit** (AU) is used for measuring "local" distances, those inside our solar system. One AU is equal to the average distance from the centre of Earth to the centre of the Sun (149 599 000 km). Astronomers use this when describing positions of the planets relative to the Sun.

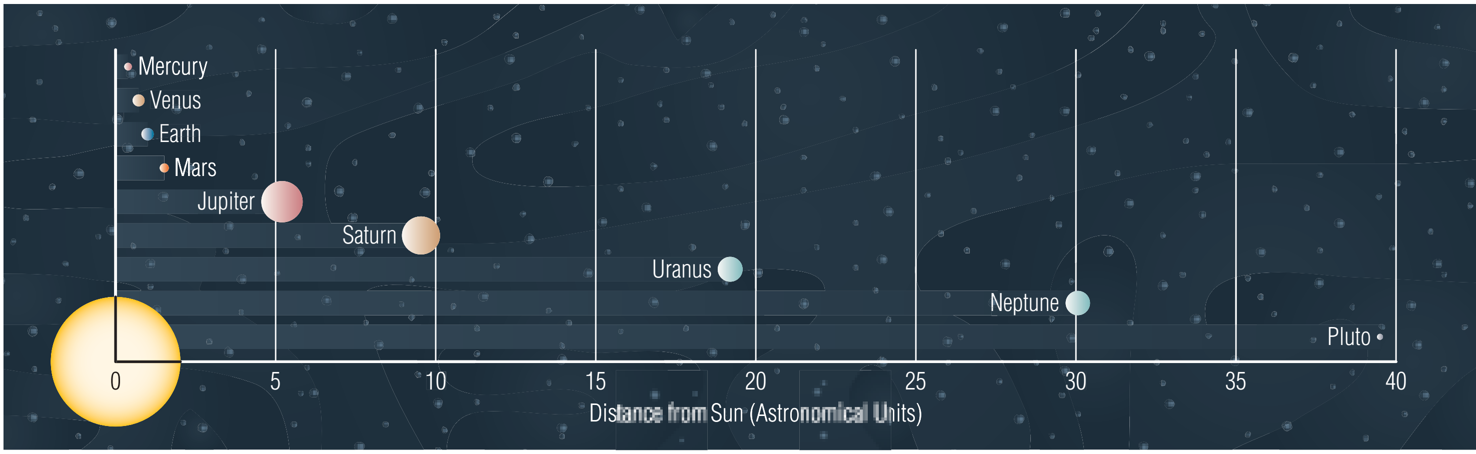

Figure 1.12 The relative distances of the nine planets from the Sun. Note that the bodies are not to accurate scale in this figure. If they were, the Sun would have to be shown with a diameter of about 57 mm.

Light-years

The vast distances beyond the solar system, out to stars and galaxies, are so great that even astronomical units are too tiny as measures. Instead, the **light-year** is used. It equals the distance that light travels in one year.

Light travels at a speed of 300 000 km/s. In a year, that adds up to about 9.5 trillion km. If you wanted to wind a string 1 light-year long around Earth's equator, you would have enough string to wrap it around *236 million times*! The distance to Proxima Centauri, the next nearest star to Earth after the Sun, is a little over 4 light-years.

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Big, Bigger, Biggest

Earth is about 1/1000 the volume of Jupiter, our solar system's largest planet. Jupiter is about 1/1000 the volume of the Sun. The Sun is about 1/300-millionth the volume of the star Betelgeuse (located in the constellation of Orion).

ACTIVITY E-1

Inquiry

HOW BIG IS THE SUN?

The Question

Can we accurately measure the diameter of the Sun by using an indirect method?

Procedure

1. Working with a partner, tape a piece of cardboard to each end of the metre-stick. Then tape the piece of aluminum foil over the square opening in one piece of cardboard, and tape the white paper in the middle of the other piece of cardboard.

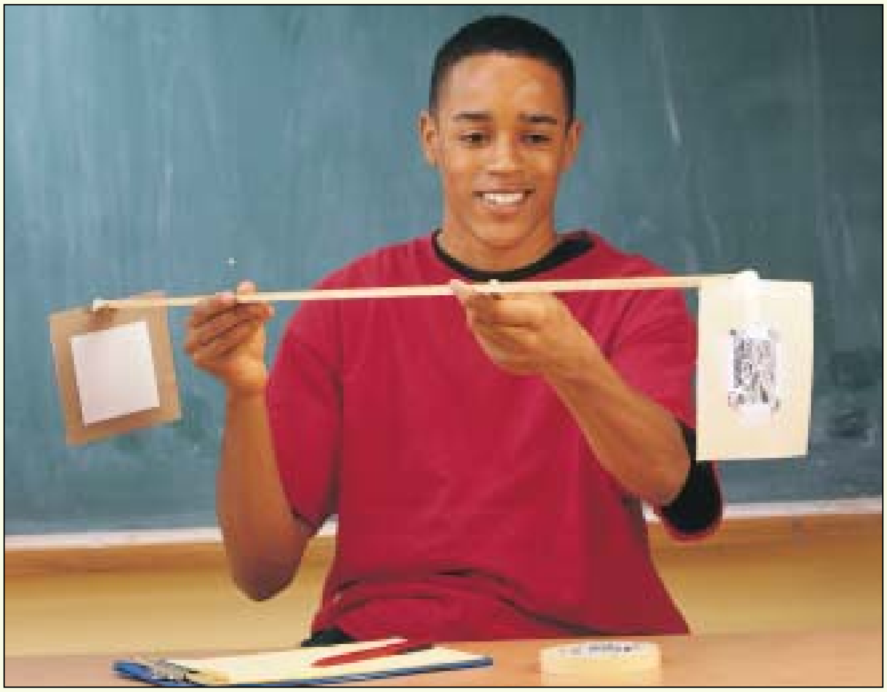

Figure 1.13 Step 1

2. Using the compass point, poke a small hole (about 1 mm in diameter) in the aluminum foil. Be careful not to make the hole any larger than that.
3. Take your apparatus and a pencil outside. (This procedure can be carried out even on a slightly cloudy day, as long as the Sun can still cast a shadow.)
4. One partner holds the metre-stick horizontally with the aluminum piece pointing toward the Sun. He or she should move the end of the metre-stick around until the Sun shines through the pinhole and forms a circular image on the piece of white paper. (Note: The person holding the apparatus should try to steady it by resting it against his or her chest. Another option is to steady the metre-stick by resting it on a ring stand.)
5. The other partner marks the diameter of the circle with two pencil lines on the paper (see Figure 1.14).
6. Carry out steps 4 to 5 again, obtaining a pinhole image of the Sun and marking its diameter on the paper. Repeat a third time.

Caution!
Never look at the Sun directly.

Materials & Equipment

- metre-stick
- 2 pieces of cardboard, approximately 15 cm by 15 cm each (one piece of cardboard will have a 5 cm by 5 cm opening cut into its centre)
- 1 piece of aluminum foil, approximately 8 cm by 8 cm
- 1 piece of white paper, 10 cm by 10 cm
- masking tape
- drawing compass
- ring stand (optional)
- ruler
- calculator

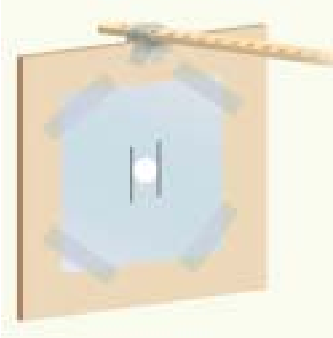

Figure 1.14 Step 5

Analyzing and Interpreting

7 Calculate the average diameter of the Sun's image. Measure the marks you made on the white paper and find the average diameter (*d*) for your three measurements (in centimetres).

8 Use the following ratio to determine the diameter of the real Sun:

$$\frac{d}{100\text{ cm}} = \frac{D}{150\ 000\ 000\text{ km}}$$

Where: *d* is in centimetres
D is in kilometres
100 cm is the distance between the cards
150 000 000 km is the distance between the Sun and Earth

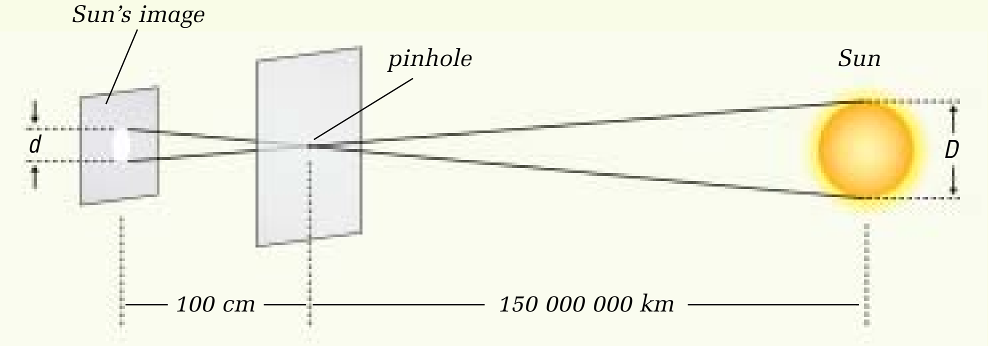

Figure 1.15 Step 8

9 In a reference book or on the Internet, look up the actual diameter of the Sun. Use that figure in the equation below to calculate the accuracy of your measured value. The "percent error" shows how far from (or close to) the real value your measured value is.

$$\text{percent error} = \frac{(\text{actual value} - \text{measured value})}{\text{actual value}} \times 100$$

10 What did you find? How accurate was your measured value of the Sun's diameter?

Forming Conclusions

11 Describe the possible sources of error that might make your measurement inaccurate.

12 Do you agree or disagree that the diameter of the Sun can be accurately measured by using an indirect means? Explain.

Applying and Connecting

13 Could you use this method of measurement to obtain the diameter of another distant body such as Jupiter? Could you use it to measure the diameters of bodies outside our solar system?

14 Why must all measurements of size and distance in space be made indirectly?

GIVE IT A TRY

TAKE A WALK THROUGH THE SOLAR SYSTEM

How has our knowledge of the solar system improved as technology has advanced? One way is that we have a better understanding of the vast distances between the planets.

Planet	Number of steps from the Sun
Mercury	less than 0.4
Venus	0.75
Earth	1
Mars	1.5
Jupiter	5
Saturn	9.5
Uranus	19
Neptune	30
Pluto	39.5

Purpose

To create a scale model of the solar system

Procedure

1. Organize into groups of 10. Each member in the group chooses to represent the Sun or one of the nine planets. Go outside to a large playing field.
2. The "Sun student" stands in place at one side of the field. He or she calls out each planet name in turn, plus the number of steps that the "planet student" must take from where the Sun is standing. (Refer to the table on the right, which shows the planet distances from the Sun at a footstep scale representing the actual distance.) Each step should be about 1 m long.

Questions

3. In a class discussion, share what you learned about distances in the solar system. What did you notice about the positions of the planets relative to the Sun?
4. How do the distances between the inner planets compare with the distances between the outer planets?

Looking into the Past

When you look at an object in space, you are seeing it as it was at an earlier time. That's because it takes time for the light from the object to travel to Earth across the great distance in space. Gaze at the Moon and you see it as it was about a second before. Light from the Sun takes about 8 min to reach Earth. Light from the planet Pluto, visible with the aid of a telescope, takes an average of about 5 h to reach Earth. Images of stars in the centre of our galaxy take 25 000 years to reach us.

The farther out into the universe we are able to look, the deeper into the past we see. Today's modern telescopes, for instance, are capable of collecting light that has travelled from distant galaxies. Even more astonishing are the images that the Hubble Space Telescope, launched in 1990, has captured. (You will learn more about this space-based telescope in subsection 3.1.) Astronomers believe that what the Hubble Space Telescope is viewing reaches back some 12 billion years.

Figure 1.16 Some of these stars may no longer exist, but we are only receiving their light now.

CHECK AND REFLECT

Key Concept Review

1. Name three instruments used throughout history to observe the motion of the planets and stars.
2. Explain how a sundial works.
3. What term is used to describe the distance between Earth and the Sun?
4. How far does light travel in one second?

Connect Your Understanding

5. Before the development of any technology for observing the sky, how did people map the motion of objects in the night sky?
6. Why were dependable navigation instruments important to the explorers who were crossing oceans to find new lands?
7. How did the telescope change human understanding of space?

Extend Your Understanding

8. What is the general relationship between the size of a planet and its distance from the Sun?

1.3 The Distribution of Matter in Space

When you look at the night sky from a city or town, you can see many of the brighter stars. Journey into the countryside, away from the light pollution of the city, and the night sky will appear to be completely full of stars. All of those bright points of light in space are separated by unimaginably large distances.

Figure 1.17 Using modern telescopes, astronomers have been able to study starlight from faint, remote stars, such as those in the Milky Way galaxy shown here.

WHAT IS A STAR?

A star is a hot, glowing ball of gas (mainly hydrogen) that gives off tremendous light energy. The number of stars in the universe is in the billions of billions.

Stars vary greatly in their characteristics. Our Sun has a mass 300 000 times greater than Earth, with an average density of 1.4 times that of water. In diameter, Betelgeuse is 670 times larger than our Sun, but only 1/10-millionth as dense. Stars vary greatly in their colours as well. The colour of a star depends on its surface temperature. Very hot stars look blue. Cooler stars look red.

In the 1920s, two scientists, Ejnar Hertzsprung and Henry Norris Russell, began comparing the surface temperature of stars with the stars' brightness (luminosity). When they plotted their data, Hertzsprung and Russell discovered that the distribution of star temperature and brightness is not random. Instead, as the "Hertzsprung-Russell diagram" shows (see Figure 1.18), the stars fall into several distinct groupings. Part of this pattern has since been accounted for by the current theory of how stars evolve and change over very long periods of time.

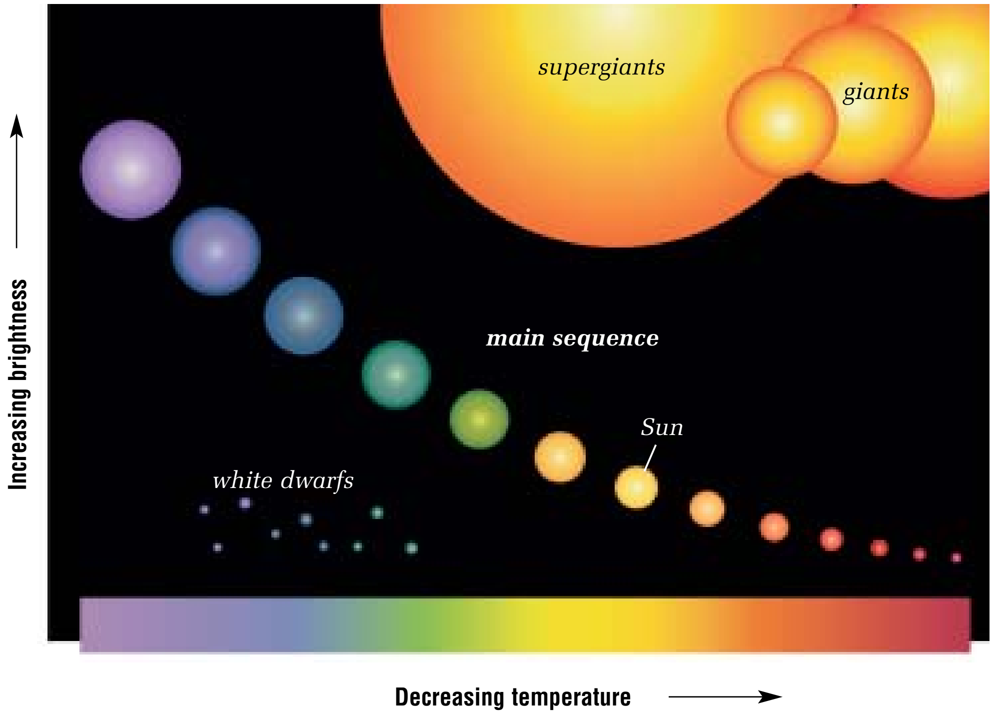

Figure 1.18 The results of graphing data from thousands of stars was the Hertzsprung-Russell (H-R) diagram. Our Sun belongs in the middle of the diagram in a grouping of stars called the *main sequence*. Ninety percent of all stars fit into this grouping.

QUICKLAB

WHAT COLOUR AND TEMPERATURE TELL US ABOUT ELEMENTS

(Teacher Demonstration)

Purpose

To observe the colour and temperature associated with different elements

Procedure

1. Light the Bunsen burner.
2. Place 10 drops of the $LiCl_{(aq)}$ in a test tube.
3. Dip a wooden splint into the test tube containing the $LiCl_{(aq)}$, moistening the splint tip.
4. Remove the splint from the test tube and hold the moistened end in the hottest part of the burner flame. Students should observe the colour and record what they see. Often the colour disappears quickly, so repeat the procedure if necessary.
5. Repeat steps 2 to 4 for each of the other solutions. In each case, students should record what they observe.

Questions

6 What was responsible for the different colours you saw?

7 What can the colour of the flame reveal?

8 How would this information be useful for astronomers studying the spectrum of a star?

Materials & Equipment

- 8 test tubes (75 mm by 100 mm)
- test-tube rack
- wood splints
- Bunsen burner
- closed fume hood
- solutions of $LiCl_{(aq)}$, $KCl_{(aq)}$, $NaCl_{(aq)}$), $CuCl_{2(aq)}$, $BaCl_{2(aq)}$, $SrCl_{2(aq)}$, $CaCl_{2(aq)}$

Caution!
The materials in this demonstration can be hazardous if inhaled. Observe the reactions from a safe distance.

*info***BIT**

Meet a Really Big Star

Our Sun is a very average star in the middle part of its life. How average is it? Stand 1 m away from the wall. This distance represents the Sun's diameter. At this scale, the diameter of the largest star now known would be 2300 m (2.3 km).

THE BIRTH OF A STAR

Just as every living thing on our planet is born, lives, and dies, a star has a life cycle, too. Stars form in regions of space where there are huge accumulations of gas and dust called **nebulae**. Each nebula is composed of about 75% hydrogen and 23% helium. The other 2% is oxygen, nitrogen, carbon, and silicate dust. Some of this **interstellar matter** came from exploding stars.

The attraction of gravity acting between the atoms of gas and grains of dust can cause a small area of the nebula to start collapsing into a smaller, rotating cloud of gas and dust. As more material is drawn into the spinning ball, the mass at its core increases and the temperature climbs. If the core gets hot enough, it will start to glow. This is a **protostar**, the first stage in a star's formation. As the process of "star-building" continues, the interior of the protostar gets hotter and hotter. When the core reaches 10 000 000°C, hydrogen starts to change to helium. This process, known as fusion, releases great quantities of energy and radiation. A star is born.

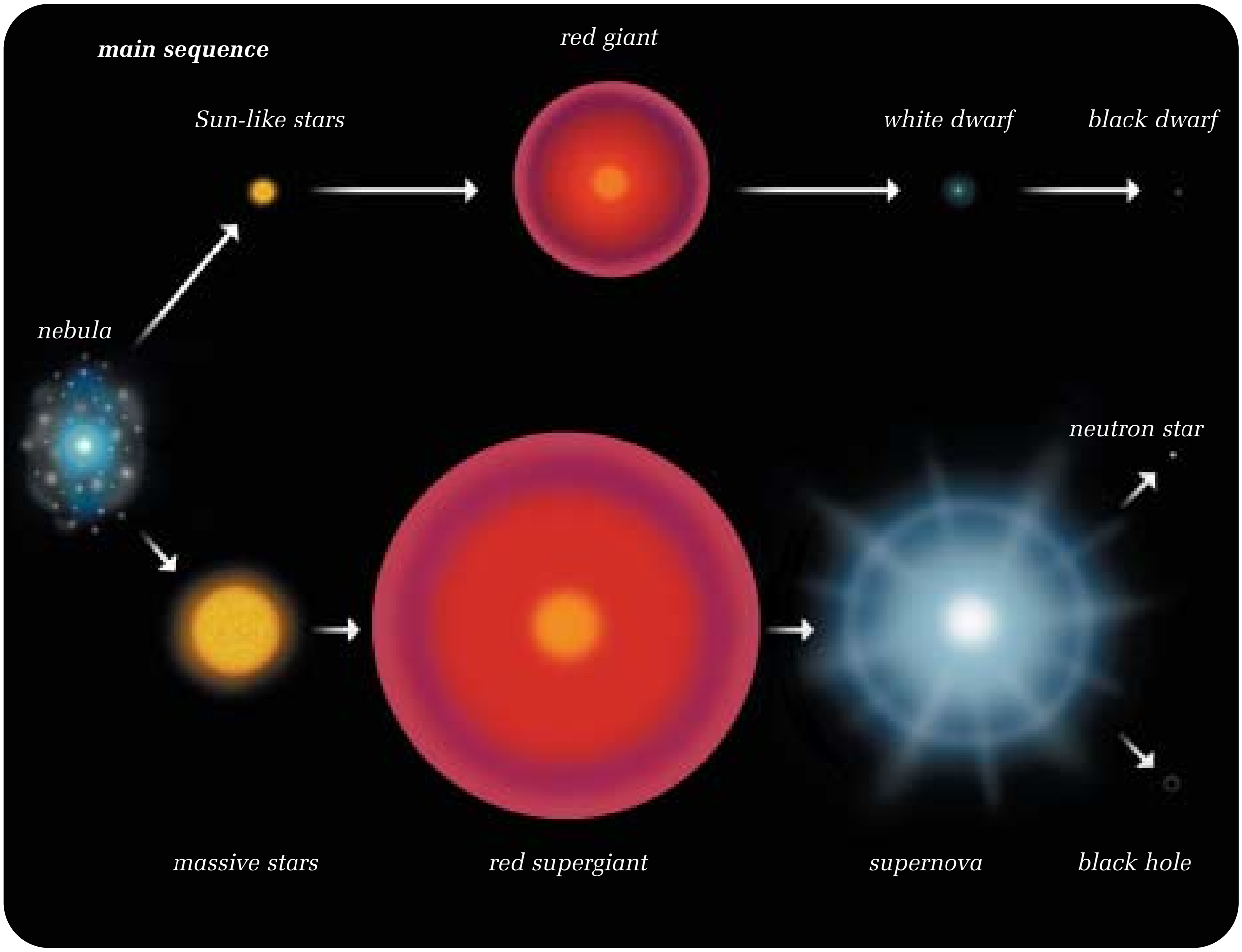

Figure 1.19 From nebular material, stars form with a variety of masses. The life cycles of massive stars differ from those of Sun-like stars.

The Life and Death of Stars

Depending on the mass of the star formed from a particular nebula, the star will be **Sun-like** (in terms of mass) or **massive**. Both types of stars spend most of their lives in this **main sequence**, converting hydrogen to helium in their cores. The outward pressure of radiation on the stellar material is counteracted by gravity, so the stars are in a stable state. All stars remain in this state for millions to even billions of years.

Just as fuel in the gas tank of a car eventually runs out, so does the fuel in a star. When the hydrogen in the core has been used up, the stable-state star shrinks in size, heating the helium core so that it first starts fusing to carbon, then to other elements. As gravity causes the star to contract, further nuclear reactions occur, leading to expansion of the outer layers. In this way, the star becomes larger, turning into a **red giant** if it is a Sun-like star, or a **red supergiant** if it is a massive star. Our Sun will become a red giant in about 5 billion years. At that time, the Sun's diameter may extend out past the present orbit of Mars.

The final stage in a star's life occurs when the fusion reaction stops. For a Sun-like star, fusion ends when the core temperature in the star is no longer hot enough to keep the reaction going. With no heat input from fusion, the decreasing pressure is unable to prevent gravity from causing the star to collapse slowly on itself. The Sun-like star continues to shrink, gradually becoming a **white dwarf**, no larger than Earth. Eventually, the star will fade completely until it evolves into a cold, dark **black dwarf.** According to physicists, it takes so long for a white dwarf to cool that no black dwarf may yet have had time to form in the universe.

In a massive star, the fusion reaction stops when the star runs out of fuel. The lack of heat input into the core from fusion enables gravity to get the upper hand. In this case, gravity causes the star's core to collapse rapidly on itself. The collapse ends suddenly with an outgoing shock wave. This in turn causes the outer part of the star to explode in a catastrophic event known as a **supernova**. If the star is not destroyed entirely by the explosion, the core is left as a **neutron star** or a black hole. A neutron star is a rapidly spinning object only about 30 km in diameter. A **black hole** is a highly dense remnant of a star in which gravity is so strong that not even light from the radiation going on inside the remnant can escape.

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Too Much to Swallow

Some stars become neutron stars when they collapse. A teaspoon of material from a neutron star is so dense it would have a mass of 100 000 t.

Figure 1.20 The giant galactic nebula NGC 3603. At the upper left of the image is the blue supergiant star, Sher 25. Near the centre is a star cluster dominated by young hot stars. The enormous pillar of gas is sculpted by the stellar outflow winds created as the new stars form.

reSEARCH

Black Holes

Astronomers are discovering that black holes are more common than was first expected. Research how black holes form and where they can be found. Begin your search at www.pearsoned.ca/scienceinaction.

Black holes are themselves invisible to telescopes. Astronomers only know about their existence indirectly because of how material near a black hole becomes very hot and bright.

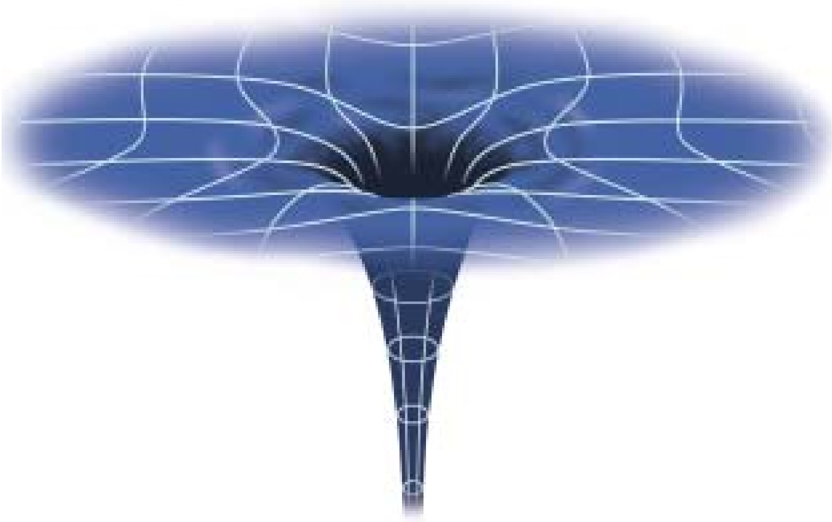

Figure 1.21 Occasionally, massive stars collapse on themselves with such violence that they become super-dense. The gravity around these bodies is so intense that even light cannot escape being pulled inward. These bodies are called black holes.

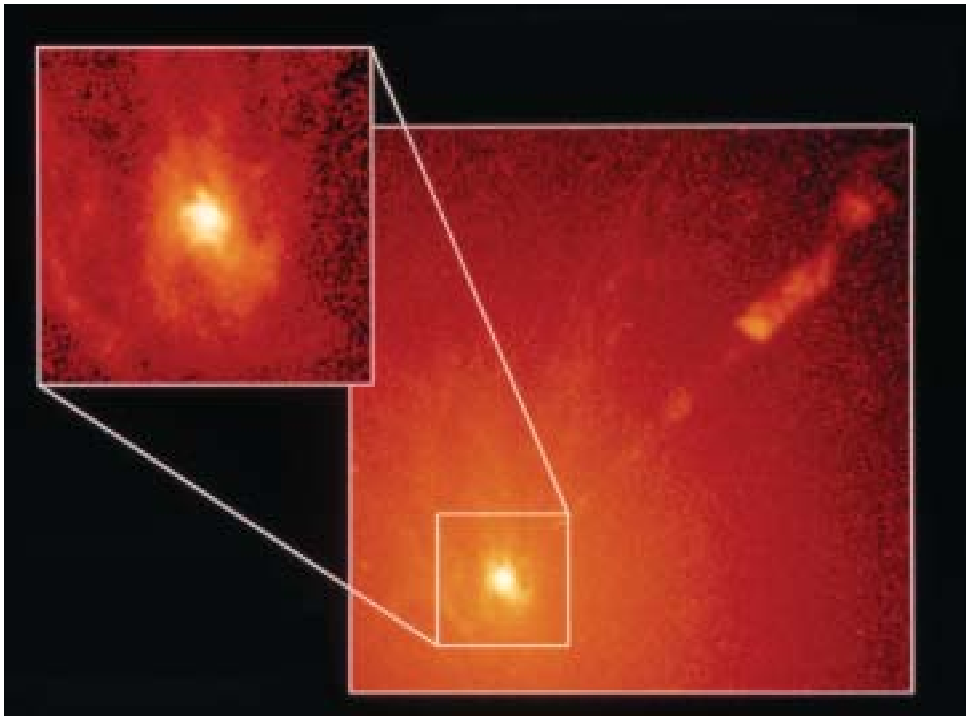

Figure 1.22 A supermassive black hole in the galaxy M87. The inset image shows stars and gas orbiting the galaxy's bright nucleus. By calculating the speed of the orbiting material, astronomers have concluded that the nucleus contains a black hole about 3 billion times the mass of our Sun. The large image shows a bright band of material that may be super-heated gas ejected from the black hole.

GIVE IT A TRY

CLASSIFYING STARS BY SIZE

The great variety of stars in the sky can be grouped in any number of ways, including by colour, temperature, and age. Another way to classify stars is by their size.

1. The list below contains information about a number of imaginary stars. In your notebook, make four columns with the headings: Red Supergiants, Giants, Main Sequence Stars, and White Dwarfs. Categorize each of the stars under the appropriate heading.

Star	Radius (Sun=1)	Density (Sun=1)	Mass (Sun=1)
Beta Brittanee	40.0	0.00014	6.0
Krueller's Star	0.7	6.3	0.5
34 Pygmi A	2.3	1.8	2.0
Von Wendle's Star	0.018	71 000	0.41
Shecky	776.0	0.000003	20.0
15 Ashlee Pi	35.0	0.00018	7.0
Scorpo-3	0.022	90,000	0.73
Prilcyon	1.5	0.9	1.8
R Schminky-5	999.0	0.0000005	18.0
Iaetapi	87.0	0.00006	5.0

2. When you have completed your classification, answer the following questions.
   a) What did you base your classifications on?
   b) What did you notice about the very small stars?
   c) What did you notice about the densities of the giants and supergiants?
   d) Black holes form when certain types of stars collapse on themselves. There are two stars on your list that have the potential to become black holes. Using the data in the table, explain which two stars you think could become black holes.

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Human Star Power

"We are stardust" is a line in the chorus of a popular song from the 1970s. It sounds like a far-fetched idea, but in fact it's true. Humans are carbon-based life forms. The carbon making up our bodies was created inside ancient stars that exploded, distributing their elements in our region of the galaxy.

STAR GROUPS

Constellations are the groupings of stars we see as patterns in the night sky. Officially, there are 88 constellations recognized by the International Astronomical Union. As well, there are many unofficially recognized star groupings. These are **asterisms**. One of the most famous asterisms visible from the northern hemisphere is the Big Dipper, which is part of the constellation Ursa Major. The ancient Greeks saw the stars that make up Ursa Major as a bear. The early Black Foot nation of North America also saw a bear. Ancient Europeans saw a variety of different patterns including a chariot, a wagon, and a plough. Figure 1.23 shows two common star patterns and their associated constellations as we know them today.

Figure 1.23 (a) The constellation of Orion, a figure in Greek mythology who was thought of as a great hunter. Note the three bright stars making "Orion's Belt." Betelgeuse is the star at Orion's right shoulder.

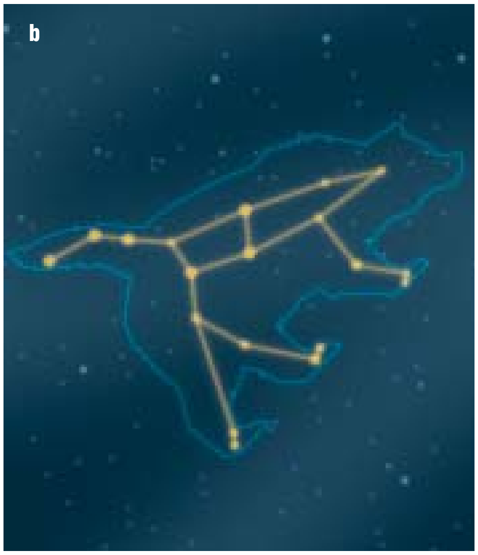


Figure 1.23 (b) The Big Dipper forms part of the constellation of Ursa Major, or the Great Bear.

GALAXIES

A **galaxy** is a grouping of millions or billions of stars, gas, and dust. It is held together by gravity.

The galaxy we live in is a spiral galaxy called the Milky Way. It is shaped like a flattened pinwheel, with arms spiralling out from the centre. Viewed from the side, a spiral galaxy looks a little like a compact disc with a marble in the middle sticking out evenly on either side. Our galaxy is believed to contain from 100 billion to 200 billion stars. There are two other main types of galaxies: elliptical and irregular. Astronomers have estimated there may be a billion billion galaxies in the universe.

Figure 1.24 Viewed from above or below the plane, a spiral galaxy appears to have long curved arms radiating out from a bright central core. Young stars provide most of the light in the arms. Older stars provide most of the light in the central region.

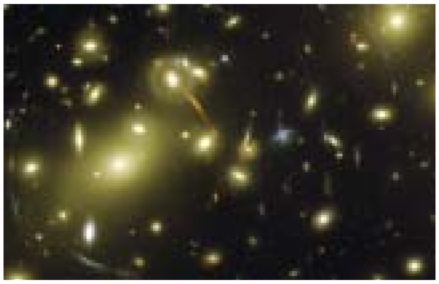


Figure 1.25 An elliptical galaxy has a shape similar to that of a football or egg and is made up mostly of old stars. This picture shows many elliptical galaxies.

Figure 1.26 An irregular galaxy has no notable shape and tends to be smaller than the other two galaxy types. A mixture of old and young stars is found in irregular galaxies.

CHECK AND REFLECT

Key Concept Review

1. What is the main chemical element in a star?
2. What is the connection between a supernova and a black hole?
3. What is the term used to refer to a group of millions of stars?
4. Explain the Hertzsprung-Russell diagram in your own words.

Connect Your Understanding

5. True or false: "Stars exist with every combination of brightness (luminosity) and temperature. No specific patterns exist when star data with these characteristics are plotted." Explain your answer with reference to the Hertzsprung-Russell diagram.
6. Why are nebulae sometimes referred to as "stellar nurseries"?
7. Create a word sequence that correctly summarizes the life cycle of massive stars. Use the words: red supergiant, nebula, supernova, massive star, neutron star. Connect each word with an arrow (⟶).
8. Considering the number of stars in space, why don't astronomers see greater numbers of dwarf stars?

Extend Your Understanding

9. Imagine two stars in a galaxy. Both are at the end of their life spans. One star ends up as a white dwarf, the other ends up as a black hole. Describe the conditions that led to these stars having different outcomes.
10. The light we see from the planets in our solar system is just the light reflected from the Sun. Why do planets appear brighter than the vast majority of stars we see?

mathLink

The Power of the Sun

A watt (W) is a measure of power. A megawatt (MW) is a million watts. Most household items do not require that much power. For example, a typical light bulb requires 100 W to work. The Sun releases 380 billion billion megawatts every second. How many 100-W light bulbs could the Sun power?

1.4 Our Solar Neighbourhood

In Section 1.3, you learned that stars are born in stellar nurseries called nebulae. The formation of our solar system, including the Sun and nine planets, occurred in much the same way.

The "protoplanet hypothesis" is a model for explaining the birth of solar systems. The process can be described in three steps:

1. A cloud of gas and dust in space begins swirling.
2. Most of the material (more than 90%) accumulates in the centre, forming the Sun.
3. The remaining material accumulates in smaller clumps circling the centre. These form the planets.

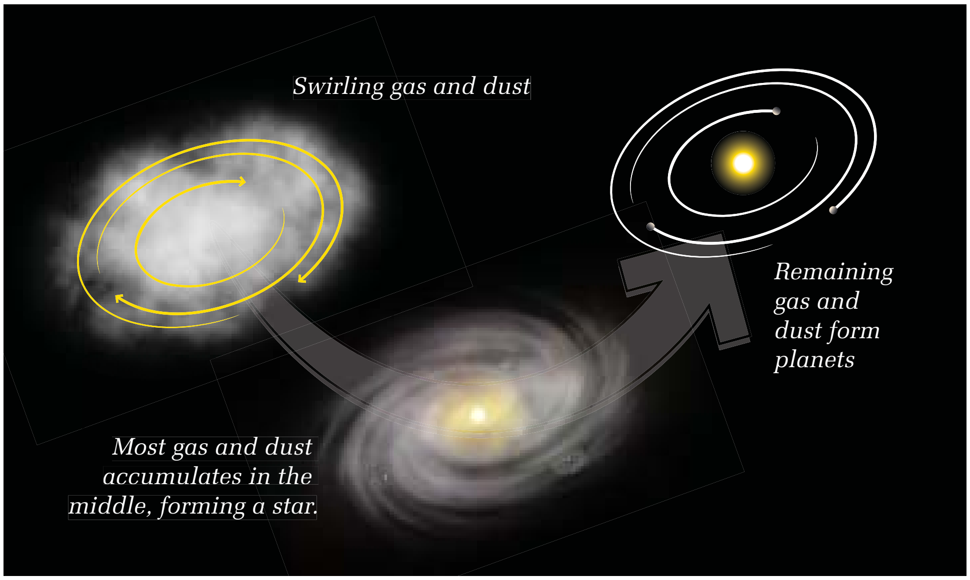


Figure 1.27 The three stages in the formation of a solar system, according to the protoplanet hypothesis (sometimes known as the "nebular theory")

THE SUN

At the centre of our solar neighbourhood sits the Sun. For thousands of years, we learned all we knew about the Sun from looking at it, and that wasn't easy to do. After telescopes were invented it wasn't long before filters were designed to allow observers to gaze directly at the Sun. Satellites have offered an even closer look. The Sun is almost 110 times wider than Earth. If the Sun were a hollow ball, almost a million Earths would be required to fill it.

The temperature at the surface of the Sun, which is constantly bubbling and boiling, is about 5500°C, while the core is close to 15 000 000°C. The Sun releases charged particles that flow out in every direction. This **solar wind** passes Earth at an average speed of 400 km/s. Earth is protected from the solar wind by its magnetic field.

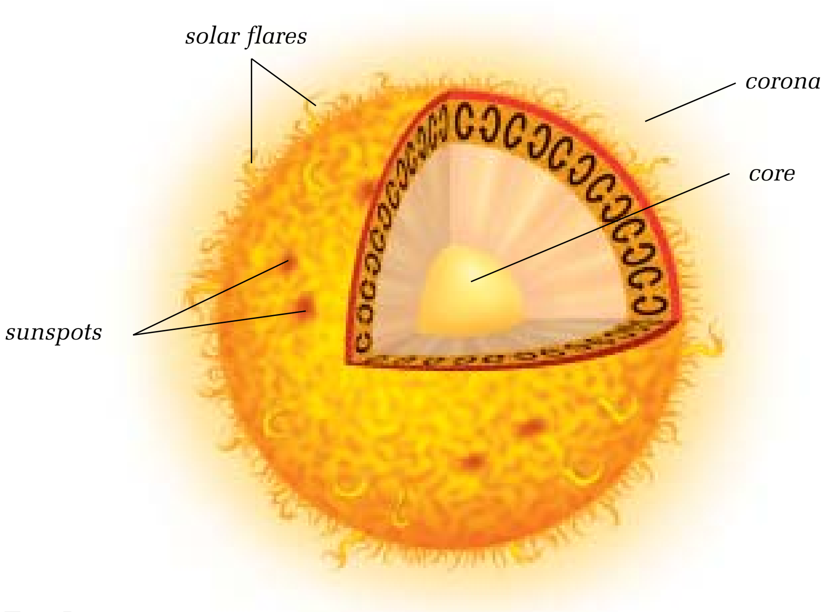


Figure 1.28 The Sun, like most stars, is made up of two main gases, hydrogen and helium. They are packed very densely at the core, held together by gravity.

THE PLANETS

The planets that make up our solar system are as different as the people that make up a family. Every planet has its own unique features and characteristics. The solar system can be divided into two distinct planetary groups: the inner planets, also called terrestrial, or Earth-like, planets; and the outer, or Jovian (in reference to Jupiter), planets. The terrestrial planets tend to be smaller, rockier in composition, and closer to the Sun than the Jovian planets. The Jovian planets are large and gaseous and are located great distances from the Sun.

Technology has enabled us to learn a lot about our nearest neighbours in space. All the planets except Pluto have been visited by orbiting space probes. Mars and Venus have had robots land on their surface.

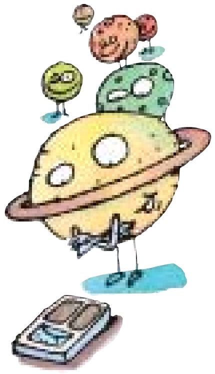
SKILL PRACTICE

BUILDING A PLANETARY SPREADSHEET

In this subsection, you will learn about many of the characteristics of the bodies that make up our solar system.

As you work through this section, prepare a single spreadsheet to compare and contrast all the information provided on pages 394–396 about the planets. You may choose to organize your spreadsheet with the planets down the left-hand column and characteristics across the top, or planets across the top and characteristics down the left-hand column. A sample characteristic could be “Atmosphere” and the data could be a simple yes or no answer.

With a small group, think up eight questions that could be used to test a person’s knowledge of how the planets compare to one another. For example: Which planet has the smallest mass? Does Jupiter complete its orbital revolution faster or slower than Saturn? As a class, exchange your questions.



Mercury

Most of what we know about Mercury has been determined by telescopes and satellite data.
Mercury is the closest planet to the Sun. Its surface is very similar to that of the Moon. Like the Moon, Mercury has no atmosphere and therefore no protection from the bombardment of meteroids, asteroids, and comets. The scars of millions of years of impacts can be seen. Other parts of Mercury's surface are smooth, probably due to lava flowing through cracks in the rocky crust. The temperatures on Mercury vary greatly, from over 400°C on the sunny side to –180°C on the dark side.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density Earth=1	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
0.39	0.38	0.06	1	0	180	59 days	0.017	88 days

Venus

Venus is similar to Earth in diameter, mass, and gravity, and is often called Earth's twin. A closer look at conditions on Venus's surface shows where the similarities end. Venus would be horrific for humans to visit. Surface temperatures are kept hot due to a greenhouse effect caused by thick clouds. Temperatures can be over 450°C—hot enough to melt lead. The atmospheric pressure is about 90 times that on Earth. The surface of Venus cannot be seen by telescope because of its thick cloud cover. The permanent clouds are made of carbon dioxide, and it often rains sulfuric acid (the same acid found in a car battery). Russians landed a probe on Venus in 1982, but it only lasted there for 57 min. In 1991, the spacecraft *Magellan* mapped Venus using radio waves (radar). It found huge canyons, extinct volcanoes, and ancient lava flows. Venus is one of the only planets in the solar system to rotate from east to west—opposite to the other six.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
0.72	0.95	0.86	0.96	0	480	243 days	0.004	225 days

Earth

Earth is unique in the solar system for several reasons. It is the only planet where water exists in all three phases: solid, liquid, and gas. It is also the only planet that is at the appropriate distance from the Sun to support life as we know it. As well, Earth's atmosphere provides protection from cosmic rays and ultraviolet radiation that would otherwise harm life. Seventy percent of the planet's surface is covered in water. Earth is one of the few places in our solar system that has active volcanism.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
1	1	1	1	1	15	23.93 h	1	365.25 days

Mars

Mars has been studied by telescope for centuries. Two missions have successfully landed robotic probes on the surface of the planet: *Viking* in 1976 and *Mars Pathfinder* in 1997. Mars is often referred to as the "red planet," though it is actually more orangey. This is caused by the iron oxides on the planet's surface. Mars has two polar ice caps, one made up of frozen carbon dioxide and water, the other of just carbon dioxide. The atmosphere is very thin and composed mainly of carbon dioxide. Although the average surface temperature is extremely cold, temperatures at Mars's equator can reach 16°C in the summer. Like Venus and Earth, Mars has canyons, valleys, and extinct volcanoes. Mars also has two small moons, Phobos and Deimos.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
1.52	0.53	0.11	0.71	2	–53	24.6 h	0.98	607 days

Jupiter

Jupiter has been observed through telescopes since the 1600s. The *Voyager* probes visited Jupiter and many of its 16 moons in 1979, followed by the *Galileo* probe in the mid-1990s. Jupiter is the largest of all the planets in the solar system, and contains more than twice the mass of all the other planets combined. It is a gas giant composed mainly of hydrogen and helium, and scientists speculate that if Jupiter were only 10 times larger than it is, it may have formed into a star. The Great Red Spot on Jupiter is a huge storm in its atmosphere. Jupiter has three very thin rings.

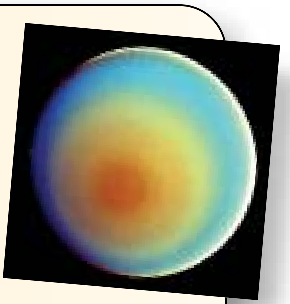
Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
5.27	11.25	318	0.24	28	–108	9.85 h	2.4	11.9 years

Saturn

Galileo saw Saturn's rings with his primitive telescope in 1610, though he initially thought they were a group of planets. *Voyager 1* and *2* flew by Saturn in 1980 and 1981, respectively. In late 2004, the *Cassini* spacecraft will reach Saturn and drop a probe onto Titan, the largest of the planet's 19 moons. Saturn is the second largest planet in our solar system and has the most distinctive ring system of all the nine planets. Over a thousand rings exist, composed of pieces of ice and dust that range in size from grains of sand to house-sized blocks. Saturn's composition is similar to Jupiter's—mostly hydrogen and helium. Because of the planet's quick rotation, wind speeds at Saturn's equator have been estimated at over 1800 km/h.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
9.54	9.45	95	0.13	19	–180	10.38 h	2.3	29.5 years

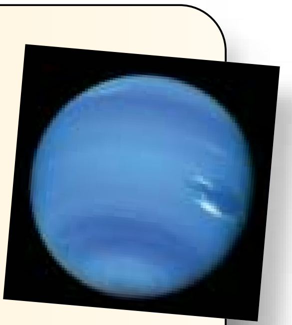
Uranus



Voyager 2 has given us most of our close-up information about Uranus, last sending data back to Earth in 1986 before it left the solar system. Satellite and telescope analyses have provided other interesting details. Uranus has one of the most unusual rotations in the solar system: its axis of rotation is tilted toward the plane of its orbit, making it appear to roll during its orbit. Another gas giant, Uranus is composed mainly of hydrogen and helium. Methane in its atmosphere gives the planet a distinctive blue colour. Uranus has a large ring system, and 17 moons.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
19.19	4.01	15	0.21	17	–214	17.4 h	2.2	84 years

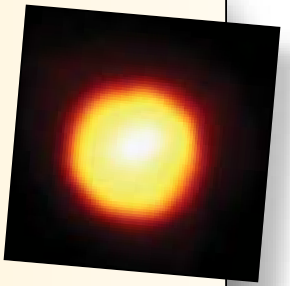
Neptune



When scientists observed the orbit of Uranus to be different from what they had calculated, they searched for an eighth planet. In 1846, they found Neptune. About a century and a half later, *Voyager 2* flew to Neptune to collect more information. The composition and size of Neptune make it very similar in appearance to Uranus. Another gas giant composed of hydrogen, helium, and methane, Neptune (like Uranus) is bluish in colour. Very little of the Sun's energy reaches the eighth planet. Neptune gives off about 3 times more energy than it receives. It boasts the fastest wind speeds in the solar system, at 2500 km/h. Like all the other gas giants, Neptune has its own ring system, as well as eight moons.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
30.06	3.96	0.17	0.27	8	–220	16.2 h	1.6	165 years

Pluto



Pluto was discovered by telescope in 1930. Since then, the most useful information about it has come from the Hubble Space Telescope. One of the greatest debates among planetary astronomers currently is whether Pluto is a planet or not. It is a frozen ball of methane smaller than our moon. It doesn't fit the pattern of the outer planets, which tend to be large and gaseous, and it isn't rocky like the terrestrial planets. Pluto's orbit is raised 17.2° from the plane of the other planets and is more elliptical than that of other planets. Like Venus and Uranus, Pluto rotates from east to west. Between 1979 and 1999, Pluto was closer to the Sun than Neptune. Some astronomers believe that Pluto and its moon, Charon, are comets captured by the Sun's gravity from the area of debris on the outer edge of the solar system called the Kuiper Belt.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
39.5	0.19	0.002	0.36	1	–230	6.39 days	0.17	248 years

OTHER BODIES IN THE SOLAR SYSTEM

Asteroids

Between the orbits of Mars and Jupiter lies a narrow belt of small, rocky or metallic bodies travelling in space. These are called **asteroids**. They can range in size from a few metres to several hundred kilometres across. The largest asteroid, called Ceres, is over 1000 km wide. Scientists aren't certain where the asteroids came from.

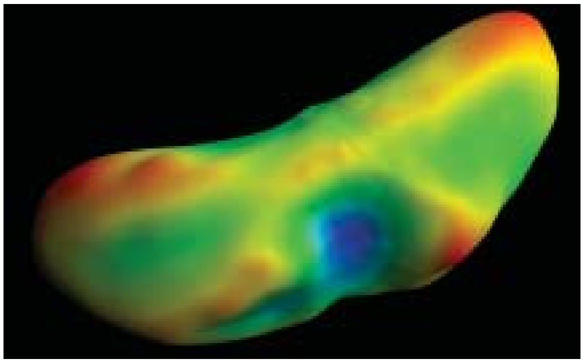


Figure 1.29 The asteroid Eros is only 33 km long and 13 km wide. This image was taken in March 2000 by *NEAR Shoemaker*, the first spacecraft to orbit an asteroid. In February 2001, the spacecraft landed on Eros.

GIVE IT A TRY

HOW CAN COLLISIONS OCCUR IN ALL THAT SPACE?

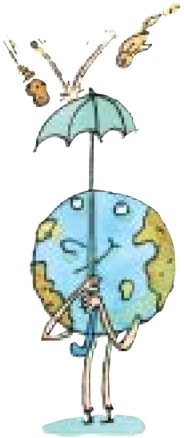
The motion of the planets in our solar system is generally regular and predictable. Even the motion of many smaller bodies in the solar system, such as asteroids and comets, has been charted and calculated. Every once in a while, however, the gravitational force of a planet or a moon can affect the path of a smaller object and send it on a course toward the Sun. Even though Earth's orbit may be in the way of that new path, chance plays an important role in determining whether a collision between Earth and the object will occur or not.

1. Out on the school grounds, your teacher will stand in place and swing a tetherball, volleyball, or similar type of ball in a slow circle overhead. The ball will be attached to a 3-m piece of cord. The ball represents Earth in its orbit around the Sun (your teacher).
2. Your teacher will provide you with one or two small soft projectiles, such as beanbags or marshmallows.
3. Stand at least 1 m outside the arc made by the swinging ball. Using a gentle underhand lob, throw your projectile toward the moving target—orbiting "Earth." If you succeed in hitting Earth, you will hear the impact or see the projectile deflect off the ball.
4. After everyone in the class has had a throw or two, add up the number of hits that occurred. Are you surprised by the number? Why? What made this challenge difficult? What would increase the chances of making contact with the ball?
5. Back in your classroom, write a paragraph describing how your observations in this activity might be related to the occurrence of collisions between Earth and other small objects in the solar system.

Materials & Equipment

- ball (such as tetherball or volleyball) with ring attachment
- 3-m piece of cord
- small, soft projectiles (such as beanbags or marshmallows), 2–3 per student

Caution!
When throwing any object, do so gently and aim only at the intended target.



Comets

Comets, often described as "dirty snowballs," are objects made up of dust and ice that travel through space. Their long tails and bright glow only appear when they get close to the Sun. When that happens, the Sun heats the materials on the comet and gases are released. These gases then get pushed away from the comet by the solar wind. The tails of some comets can be millions of kilometres long.

Comets spend most of their time slowly orbiting in the outer reaches of the solar system. Only when an event, such as the close passing of another body, occurs might a comet's path be pushed toward the inner solar system. Then a comet can end up in a regular orbit around the Sun. Comets that orbit the Sun will make a predictable appearance because their paths are large ellipses. One of these is Halley's comet, which is visible from Earth every 76 years. The last time it was seen was in 1986.

Meteoroids, Meteors, and Meteorites

Small pieces of rocks flying through space with no particular path are called **meteoroids**. Meteoroids can be as small as a grain of sand or as large as a car. Practically invisible to most telescopes, we are usually only aware of meteoroids as they hurtle through our atmosphere. When one gets pulled into the atmosphere by Earth's gravity, the heat of atmospheric friction causes it to give off light and it is known as a **meteor**. These are the so-called "shooting stars" that can often be seen streaking across the night sky. If a meteor lasts long enough to hit Earth's surface, it is called a **meteorite**. Some meteor showers are predictable, such as the Leonids.

Figure 1.30 Meteorites are rocky or metallic in composition. The largest known meteorite weighs more than 60 t. It lies where it fell at Hoba West in Namibia.

Figure 1.31 Two impact craters left by a meteorite in northern Quebec

*info***BIT**

Halley's Comet's Elliptical Path

The path of a comet around the Sun is elliptical. Knowing its shape allows astronomers to predict when the comet will return to pass by Earth again. Halley's comet has an average 76-year orbit. Shortly after its last visit in 1986, observers saw it brighten unexpectedly. That might mean it collided with something. We will have to see what happened when it makes its scheduled return visit in 2062.

Figure 1.32 Halley's comet

TRACKING OBJECTS IN THE SOLAR SYSTEM

As you have learned in previous sections, the paths of the major bodies in the solar system are ellipses. Because astronomers understand the nature and geometry of elliptical orbits, as well as of celestial motion, they now understand the paths of planets and their moons. This means that a variety of events can be accurately predicted, including both solar and lunar eclipses. Recall from earlier studies that a solar eclipse occurs when the Moon, passing between the Sun and Earth, casts a shadow on Earth. A lunar eclipse occurs when Earth passes between the Sun and the Moon, casting its shadow over the Moon.

Knowing so much about orbital paths and speeds, astronomers can predict eclipses well into the future. Some enthusiasts make it a hobby to plan trips wherever they can around the world to witness eclipses.

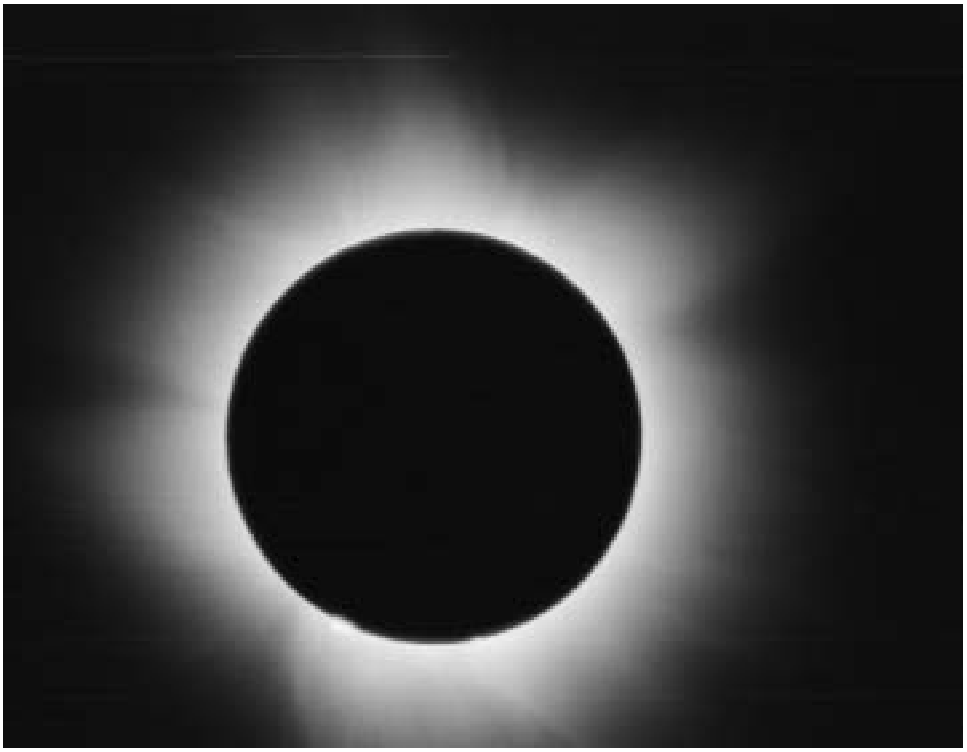


Figure 1.33 During a total solar eclipse, the Sun's corona is visible.

Understanding of orbits has also led to the discovery of many different comets. The paths of comets are elliptical, too, but larger and longer than planetary paths. Through careful observation and the use of some basic mathematics, astronomers are able to calculate the paths of some known comets and predict when they will next be close enough to Earth to be seen. Halley's comet is one example.

Tracking and discovering comets is a job shared by sky-watchers at all levels, from astronomers who work for the National Aeronautics and Space Administration (NASA) to backyard enthusiasts. NASA also has a system for tracking meteors.

reSEARCH

Other Solar Systems

Several dozen planets have been discovered orbiting other stars in our galaxy. With each discovery, astronomers are learning that our solar system is not the same as every other one. Investigate the latest research on new planets and find out how different they are from the ones in our solar neighbourhood. Begin your search at www.pearsoned.ca/scienceinaction.

Figure 1.34 The predictable path of Comet Shoemaker–Levy allowed astronomers to anticipate and monitor the comet's collision with Jupiter in 1994.

CHECK AND REFLECT

Key Concept Review

1. List the names of the inner, or terrestrial, planets.
2. Name three ways in which the outer, or Jovian, planets are alike.
3. Explain the main ways in which the inner planets differ from the outer planets in our solar system.
4. Describe what an asteroid is.
5. Why are comets sometimes referred to as "dirty snowballs"? Why are their tails visible?
6. What is the name for a meteoroid that survives its journey through our atmosphere and hits Earth?

Connect Your Understanding

7. Describe in your own words how the solar system formed.
8. On the upper surface of Jupiter's atmosphere, the attractive force of gravity is 2.5 times that on Earth. What would a bathroom scale show if a 50-kg person were weighed on Jupiter?
9. For about 20 years, from 1979 to 1999, Pluto was closer to the Sun than Neptune was. Explain why this was possible.

Extend Your Understanding

10. Why would it be unreasonable to expect Saturn-like rings around any of the inner planets?
11. Explain how it is possible for an asteroid or a comet to cut directly across Earth's orbital path but not strike Earth.
12. Suppose a gaseous planet half the size of Saturn were discovered. Where in the solar system do you think it would be located? Give a reason for your answer.

1.5 Describing the Position of Objects in Space

Suppose you were talking on the phone to your friend who lives in the house beside you. From your windows you are looking at the night sky. Your friend finds an interesting stellar object and wants you to look at it. How can you be sure you are both looking at the same thing?

To locate the position of an object in space, two questions must be answered: "How high in the sky is it"? and "In which direction"? This problem can be solved with only two measurements. The first is the compass direction, called the **azimuth**. With due north as 0° and going clockwise, the azimuth will tell you which direction to point. For example, 180° from 0° would have you pointing due south; 270° would have you pointing west. The second measurement shows how high the object is in the sky. This is called **altitude**. The altitude ranges from 0 at the horizon to 90° straight up. With these two measurements, stargazers can pinpoint objects in space. **Zenith** refers to the highest point directly overhead.

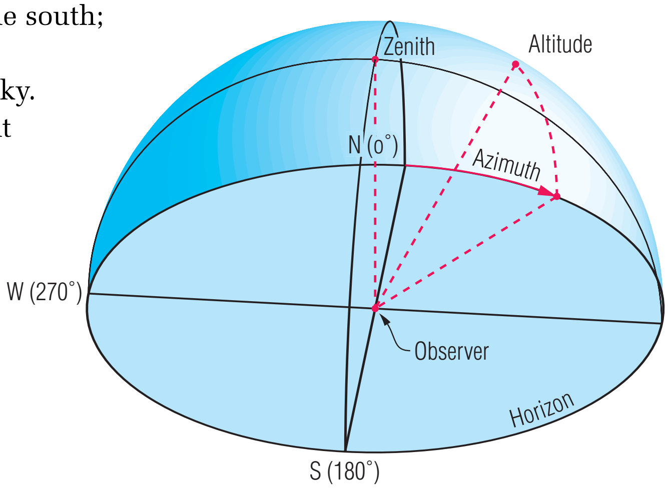


Figure 1.35 The imaginary dome that allows us to describe the position of a celestial object

GIVE IT A TRY

ESTIMATING POSITIONS IN SPACE

In this activity, you will investigate how accurately you can estimate the position of an object above you by using a simple tool, your fist.

1. From your desk, select a small object that is high up on a classroom wall. Choose the wall that is farthest from your desk. The object can be a clock, a tack, or even just the upper corner of the room.
2. Extend one arm out in front of your body and make a fist. Close one eye and look down your arm, as though you were taking aim at something. The height of your fist as you see it this way represents about 10° of altitude.
3. From a standing position beside your desk, and using your fist as described in step 2, estimate the height (in degrees) of the object you have chosen. Start with one arm held out horizontal to the floor. Then, using both arms, count the number of times you have to place one fist on top of the other until you "climbed" to the object's position. *For example: 6 fists × 10° = 60°.* Record your "altitude" estimate in your notebook.
4. Next, estimate the compass direction of the object. Your teacher will tell you where due north is. Imagine that point to be 12 o'clock in a clock face. Describe the direction in which your object lies from north (12 o'clock) by reference to its position on the imaginary clock face (e.g., 2 o'clock). Combine this with the first measure of elevation.
5. Compare the accuracy of your results with that of some of your classmates. What similarities or differences do you notice in your results? Explain why these might have occurred.

ACTIVITY **E-2**

Problem Solving

WHERE DO WE LOOK?

Materials & Equipment

- cardboard
- circle protractor
- pen
- scissors
- string
- small weight (such as a washer or rubber stopper)
- straight drinking straw
- adhesive tape
- thin straight object (such as a souvlaki stick or a straight piece of wire)

Recognize a Need

To find a particular star in the night sky is not as simple as pointing and saying, “There it is!” To find the specific location, a set of rules must be followed and accurate directions given. A star’s position is like an address to a house: no two are exactly alike. How is the position determined, and how can another person find the exact same star?

The Problem

Searching the night sky, you have discovered a bright star that wasn’t visible before—a supernova perhaps. To claim your fame as the star’s discoverer, you have to confirm its position with the Astronomical Society. The Society requests that you send the star’s bearing (azimuth) and altitude. You have a telescope, but no way of knowing the exact position of the star in the sky. The challenge is to build a device, find the star, and correctly identify the coordinates. The only way to solve the problem is to construct an astrolabe.

Criteria for Success

- Build a functioning astrolabe with materials provided.
- Locate the star with the astrolabe.
- Use the correct technique to identify the coordinates with the astrolabe.

Build a Prototype

1. Draw a semicircle about 20 cm in diameter on the cardboard. Using a protractor, mark the 10° increments on the cardboard and label them (see Figure 1.36). Cut out the cardboard protractor.

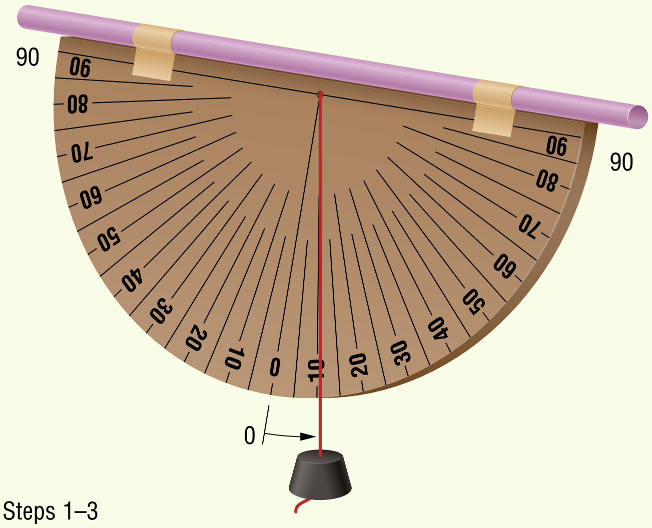


Figure 1.36 Steps 1–3

2. Tie one end of the string to the weight and attach the other end to the centre of the cardboard. The weight should be able to swing freely, as shown in Figure 1.36.
3. Tape the straw to the cardboard as shown in Figure 1.36. The angle you read from the string on your new astrolabe indicates the angle your target is above the horizontal.

Test and Evaluate

Note: For this part of the activity, your teacher will have hung a sphere (representing your star) from the ceiling.

4 Sitting at your desk, locate the “star” in the sky using the straw as a telescope. The weight should be hanging straight down (Figure 1.37).

5 Once you have found the star, hold the astrolabe as steady as possible and read the altitude off the cardboard scale (or have another student read it for you). Write this number down as “altitude” (for example: 45°).

6 Your teacher will tell you where due north is. Lay the circle protractor on your desk and align the 0° with due north. Tape the protractor on your desk to hold it in place.

7 Place the thin straight object on the circle protractor with one end at the centre of the protractor and the other end pointing in the direction of the star. The azimuth is always measured clockwise from the north in degrees. Read the angle measured clockwise from due north. This is the azimuth of the star.

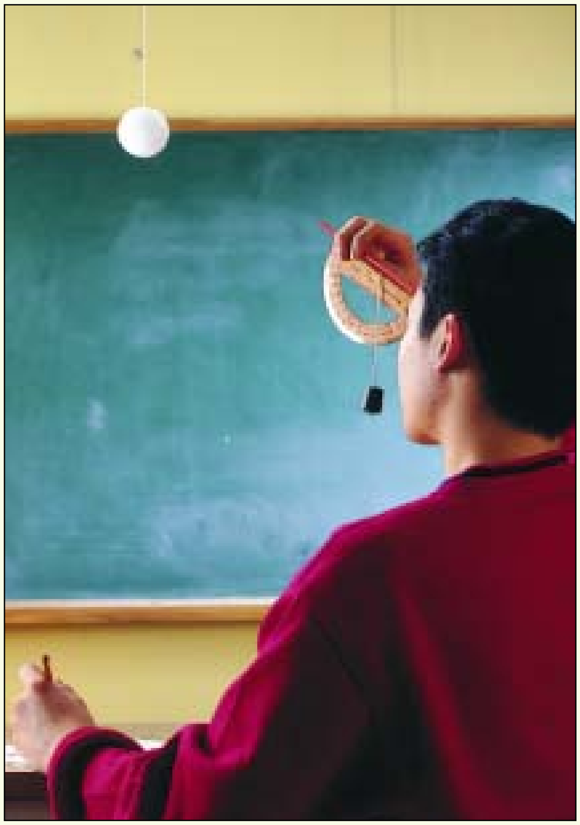


Figure 1.37 Step 4

Communicate

8 Imagine that, after locating the position of the star, you send the coordinates to the Astronomical Society. A week later they call to say they followed your directions exactly, but could not find the star. You are certain you were careful. What might have happened that would make your coordinates incorrect?

9 Do your coordinates match those of any of your classmates? Explain why they might not.

10 If it were a real star you were looking at and you took coordinates every night for one full year from the same location, would the coordinates change or remain the same? Explain your answer.

Extension

You can record the altitude of the Sun with an astrolabe. Point the straw at the Sun with one hand, and hold your other hand, palm up, to the other end of the straw. Move the straw around until you see a small circle of light on the palm of your hand. Read the angle on your cardboard scale. This shows you the altitude of the Sun. Make three measurements and calculate an average. Try this at the same time for five days in a row. Does the Sun’s altitude change or does it stay the same? Explain..

Caution!
Do not look directly at the Sun through the straw.

reSEARCH

Star-studded Flags

Stars are part of the design of the national flags of Australia, Brazil, and New Zealand and the state flag of Alaska. Find out which stars the flags depict and explain why you think that is. Begin your research at www.pearsoned.ca/scienceinaction.

DETERMINING THE MOTION OF OBJECTS IN SPACE

Because they are at such enormous distances from Earth, the stars appear to stay in one place in the sky. Only when viewed over extremely long periods of time can some stars be seen to move very slightly.

When observing planetary motion, however, a person needs to wait only a few days or weeks to see a planet change its position against the background of stars. “Planet” comes from the ancient Greek word for “wanderer.” The movement of these wandering celestial planets mystified early people. Sometimes the planets seemed to speed up over time in their movements across the sky. Other times they appeared to stand still. The path in the sky along which the Sun appears to move is called the **ecliptic**.

In section 1.1, you read about how astronomers such as Aristotle and Copernicus tried to explain the motions of the planets which, when viewed from Earth, seemed very complex. Different interpretations of the available information eventually led to new theories being proposed. An example of this was Kepler’s suggestion that the planets’ paths were ellipses and not circles.

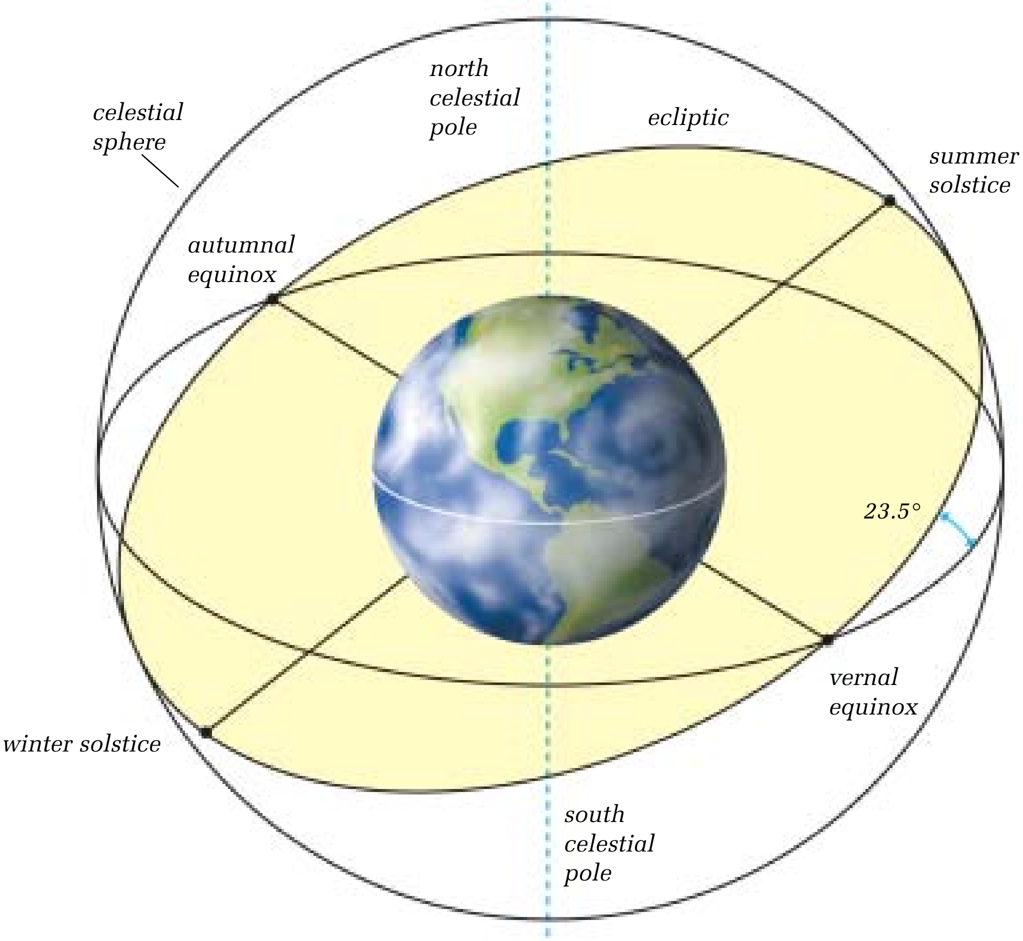


Figure 1.38 The *celestial sphere* is the name given to the very large imaginary "sphere of sky" surrounding Earth. (Think of Earth lying within a large hollow ball.) The *celestial equator* is the imaginary line around that sphere of sky directly above Earth's equator. The ecliptic—the apparent path of the Sun through the sky during the year—crosses the celestial equator at the vernal (spring) and autumnal (fall) equinoxes. The Sun's most northerly position on the ecliptic marks the summer solstice. Its most southerly position marks the winter solstice.

CHECK AND REFLECT

Key Concept Review

1. What name is given to the compass direction when we are trying to locate an object in the night sky?
2. Define altitude.
3. What is the point directly overhead called?
4. Explain what the ecliptic is.

Connect Your Understanding

5. Why did the Greeks call the planets "wanderers"?
6. Why must two coordinates, azimuth and altitude, be given to specify the location of an object in the night sky?
7. The table below has two incorrect entries.
   a) Identify each error and correct it.
   b) Explain why each of the two entries is incorrect.

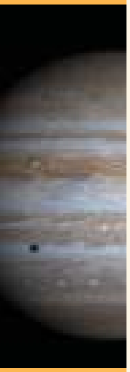
Reading	Azimuth	Altitude
1	30°	93°
2	364°	45°

Extend Your Understanding

8. Is it ever possible to specify the location of an object in the sky knowing only the altitude? Explain your answer.
9. Imagine two friends, one in Calgary and the other in Edmonton, observing the same body in space. Describe how their coordinates would be different for the same object.
10. a) Does the rotation of Earth affect azimuth and altitude measurements of stars? Explain why or why not.
    b) What can be done to ensure someone using your measurements would be able to find the object you located?

Figure 1.39 If you know the altitude and azimuth coordinates of an object in the sky, you can accurately describe its position to someone else.

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. Why was it necessary for ancient people to develop technology to better understand the motions of bodies in space?

2. Define a) astronomical unit and b) light-year.

3. What two characteristics of stars are plotted on the Hertzsprung-Russell diagram?

4. What name do we give the nuclear reaction that produces helium from hydrogen?

5. Explain the difference between a constellation and an asterism.

6. Is the Sun likely to become a neutron star? Explain your answer.

7. Imagine that you observe two stars in the night sky. One is an old star and one is a young star. What differences between the two might you observe?

8. What prevents a neutron star from collapsing under its own gravity?

9. What type of galaxy is the Milky Way? Sketch what this type of galaxy looks like.

10. a) In what way are Mars and Earth similar?
b) In what ways are they different?

Connect Your Understanding

11. Compare the general characteristics of the inner planets with those of the outer planets. Copy the table below into your notebook and fill it in.

Feature	Inner Planets	Outer Planets
Composition		
Number of moons		
Ring systems		
Size		
Surface temperature		

12. Which planet has surface features that most closely resemble Earth's? Briefly describe those features.

13. The speed of light is 300 000 km/s. The Sun is about 150 000 000 km from Earth.
a) How long does it take light to get from the Sun to Earth?
b) The distance around Earth at the equator is about 40 000 km. How long would it take light to go around the world once?

14. Explain why distances to stars are not measured in kilometres or astronomical units.

15. Describe the protoplanet hypothesis of how a solar system forms. Use sketches to support your answer.

Extend Your Understanding

16. Explain why it is necessary on Earth to have a leap year (one extra day, February 29) every four years.

17. Figure 1.40 shows the orbital paths of Neptune and Pluto. As you know from this section, Pluto's path cuts across the path of Neptune. Give two reasons why it is unlikely their orbital paths will ever collide.

Figure 1.40 Question 17

18. The greater the mass of an object, the greater its gravitational attraction. The object with the largest mass in our solar system is the Sun. Because of its large mass, it not only holds the planets in their orbits, but it also attracts great amounts of space debris from the far reaches of the solar system. On occasion, large chunks of debris have even hit Earth, but not as many as astronomers have predicted could hit Earth. What might be some explanations for Earth's apparent "luck" in not being hit by more space debris?

Focus On SCIENCE AND TECHNOLOGY

Our understanding of space and the universe around us is directly connected to the technology we use to make observations. As the technology has improved, so has our ability to find answers to our questions. Consider the following questions and use examples from your work in this section to support your answers.

1. How has technology affected the way humans look into the universe?
2. How have technological advances over time improved our understanding of space?
3. Why has distance in space proven to be such a challenging factor to overcome?

2.0

Technological developments are making space exploration possible and offer benefits on Earth.

Key Concepts

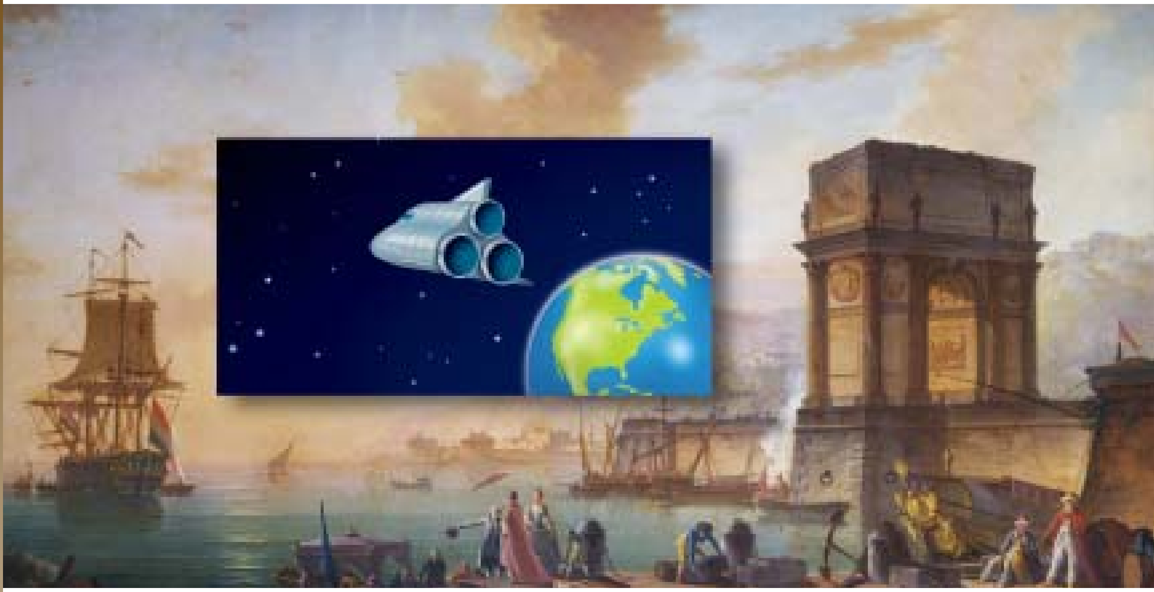
In this section you will learn about the following key concepts:

- technologies for space exploration
- life support technologies
- communication technologies

Learning Outcomes

When you have completed this section, you will be able to:

- analyze space environments, and identify challenges that must be met in developing life-supporting systems
- describe technologies for life-support systems, and interpret the scientific principles on which they are based
- describe technologies for space transport, and interpret the scientific principles involved
- identify materials and processes developed to meet needs in space, and identify related applications
- describe the development of artificial satellites, and explain the major purposes for which they are used



"From space, if you look back just a few degrees away from Earth, you see the black void of the universe—the cold vacuum of space. But when you look back at the Earth, bathed in sunlight, you see where we all live. We are all voyagers in space together."

—Roberta Bondar, Canadian astronaut, quoted in the Canadian Space Agency's "Canada in Space: Destination Earth" (1993)

The lure of leaving Earth to explore other planets and beyond is the same lure that has always drawn humans to explore what lies over the horizon. The urge to venture into uncharted seas, distant countries, and extreme environments, such as the Arctic and Antarctica, is no different than the urge to venture into space.

From the earliest unmanned rockets to the re-useable space shuttles of today, the biggest challenges of exploring space have been finding ways: 1) to go fast enough to achieve orbit around Earth or break free of Earth's gravity and travel to other planets; 2) to keep equipment operating in the extreme environment of space; and 3) to transport people out and back safely. In searching for solutions to these problems, scientists have used technology and technologists have used science.

In this section, you will learn about technologies developed to send objects into space and to make life support and transport in space possible. You will also learn about the spin-offs from such innovations that are being used here on Earth.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 Getting There: Technologies for Space Transport

Humans have come a long way since their early experiments with rocketry to propel objects high into the sky. Today, hundreds of satellites circle Earth. They transmit non-stop information for use in communications, navigation, research, and weather forecasting. Robotic space probes have investigated all the planets of our solar system except Pluto. As well, manned spacecraft—notably the Russian *Mir* space station, the American space shuttle, and the International space station—have conducted studies while in Earth's orbit.

Getting an object into "space" (outside Earth's atmosphere) first required figuring out what speed an object needed to overcome the force of gravity pulling the object back toward Earth. That speed, it was found, had to be at least 28 000 km/h.

infoBIT

The First Rocketeer

A legend from 16th century China suggests that the first rocket-assisted flight was attempted by Wan-Hu, a Chinese official. Forty-seven rockets were attached to a chair that was connected to two kites. After all the rockets were ignited, there was a massive explosion. No traces of Wan-Hu, the chair, or the kites were ever found.

*QUICK***LAB**

THE POWER OF STEAM

Note: This may be done as a teacher demonstration.

Caution!
Be careful around the heating tray to avoid getting a burn.

Purpose

To observe the power of steam propulsion

Procedure

1. Set up the apparatus as shown in Figure 2.1.
2. Fill the beaker until it is about half full of water.
3. Turn on the heating tray to boil the water.
4. When the water starts boiling, record your observations.
5. After you have completed the activity, turn off the power to the heating tray. DO NOT touch the apparatus until it has had sufficient time to cool down.

Questions

6. What made the pinwheel turn?
7. Why was the funnel put over the beaker upside down?
8. Would the pinwheel have turned if no funnel were used? Explain your answer.
9. How could you improve this set-up to make the pinwheel spin faster?

Materials & Equipment

- plastic pinwheel
- test-tube clamp
- thermometer clamp
- plastic funnel to fit beaker
- one 250-mL beaker
- water
- heating tray
- pencil and notepaper

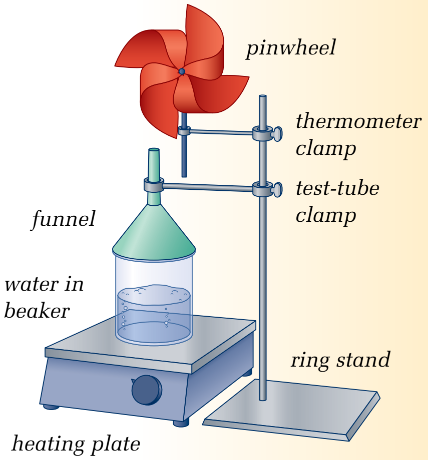


Figure 2.1 Step 1

THE ACHIEVEMENTS OF ROCKET SCIENCE

Figure 2.2 Space exploration really started once large rocket boosters were developed. Cape Canaveral in Florida is the major launch facility of the National Aeronautics and Space Administration (NASA).

Figure 2.3 Archytas's "pigeon" is said to be the first rocket ever recorded.

The first step in space exploration has been figuring out a way to get off the planet. The sophisticated rockets used today to transport unmanned and manned craft into space are tributes to human technological ingenuity and achievement. These complex rockets have far simpler origins than you might imagine. Around 400 B.C., the Greek mathematician Archytas used escaping steam to propel a model pigeon along wires. In the 1st century A.D., the Chinese were using gunpowder to make rocket-propelled arrows for battle.

On October 4, 1957, the Soviet Union became the first country in the world to launch an artificial satellite. It was called *Sputnik*, the Russian word for satellite. A month after *Sputnik* was put into orbit around Earth, the Soviet Union launched a second space capsule. This one carried an occupant, a small dog named Laika, who survived for seven days as the capsule orbited Earth. The event marked the first time any living creature had been sent into space. The valuable information gained from that mission set the path for human space travel.

Figure 2.4 *Sputnik I* was only about as large as a basketball, but its launch marked the beginning of the satellite age.

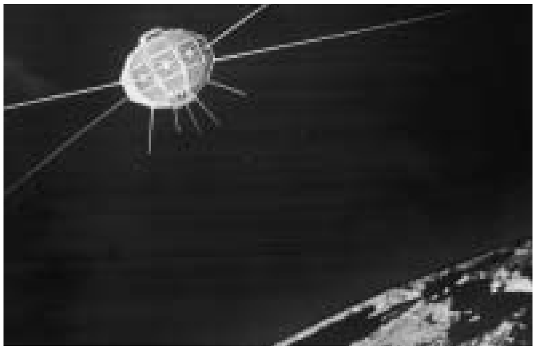


Figure 2.5 On September 29, 1962, Canada became the third nation in the world (after the Soviet Union and the United States) to launch its own satellite, *Alouette I*.

QUICKLAB

STABILIZING ROCKET FLIGHT

Have you ever wondered why rockets have fins?

Purpose

To test the effects of fins in stabilizing a rocket for flight

Procedure

1. Cut a strip about 13 cm long and 3 cm wide from the paper. Roll the strip snugly around the pencil and tape it closed to create a long tube (your "rocket"). Twist the end of the paper around the pencil point to make the nose cone.
2. Slip the pencil out the other end of the tube. Gently blow into the open end of the tube and feel for leaks along its length. If air is escaping, seal the leaks with more tape.
3. Test Flight 1: Insert one end of the straw into your rocket. With the other end of the straw in your mouth, tilt your head back slightly and blow a quick puff of air into the rocket. Observe how the rocket flies.
4. Retrieve the rocket. From the left-over paper, cut out two sets of fins. Tape these to the tube as shown below. (Hint: Adding tabs to the fins makes them easier to tape to the tube.)
5. Test Flight 2: Again, launch your rocket with the straw and observe the rocket's flight.

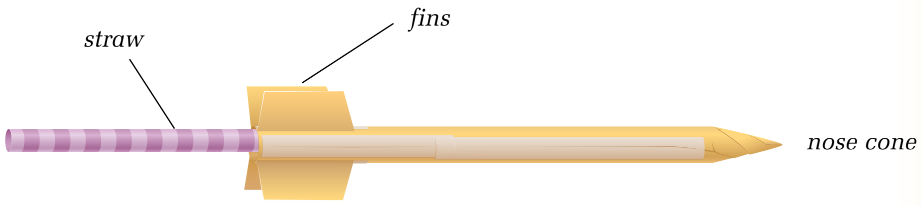


Figure 2.6 Model rocket

Questions

6 How does the rocket's performance in the first test compare to that in the second test? Write a brief conclusion about how fins affect a rocket in flight.

7 Do you think that fins would have much effect on a rocket's performance outside Earth's atmosphere?

Materials & Equipment

- a sheet of paper
- scissors
- a pencil (at least 14 cm long)
- tape
- a drinking straw (a little narrower than the pencil)

Caution!
Point your rocket in a safe direction only, away from other people.

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Space Travel Tip: Pack Lightly

When preparing a manned spacecraft for a long trip, engineers try to organize the mass of the load as follows: 3% as machinery (tanks, engines, and fins); 6% as payload (including air, water, food, satellites, crew quarters, and the astronauts), and 91% as fuel.

THE SCIENCE OF ROCKETRY

Rocketry relies on a fundamental law of physics: for every action, there is an equal and opposite reaction. An inflated balloon is similar to a simple rocket. A balloon filled with air is confining gas under pressure. Release the mouth of the balloon and it will be propelled in a direction opposite to the path of the escaping gas. Rockets also use gas under pressure confined in a chamber or tank. An opening in the chamber allows the gas to be released, producing thrust (push) and causing the rocket to be propelled in the opposite direction.

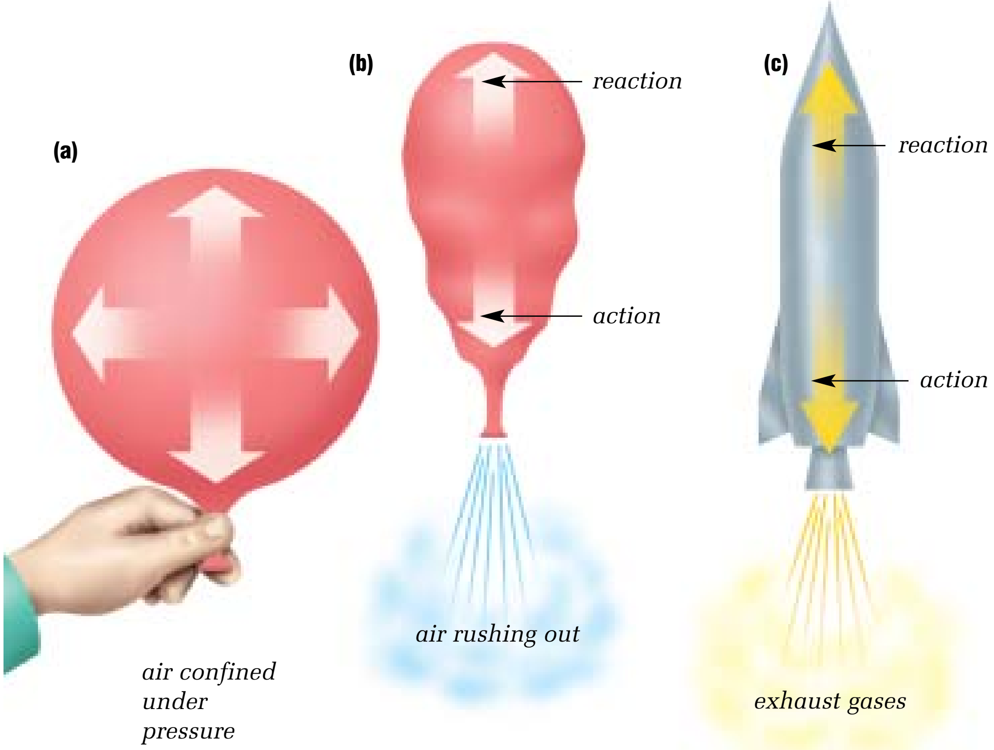

Figure 2.7 In an inflated balloon (a), the air pressure pushes equally in all directions. When the air is allowed to escape, the action causes a thrust reaction (b). Rockets are propelled in a similar way (c).

There are three basic parts to a rocket: the structural and mechanical elements, the fuel, and the payload.

- The structural and mechanical elements are everything from the rocket itself to engines, storage tanks, and the fins on the outside.
- The fuel can be any number of materials, including liquid oxygen, gasoline, and liquid hydrogen. The mixture is ignited in a combustion chamber, causing the gases to expand and leave as exhaust.
- The payload refers to the materials needed for the flight, including crew cabins, food, water, air, and people.

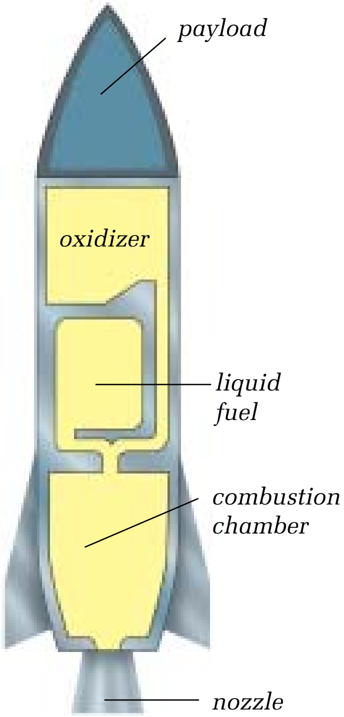

Figure 2.8 A modern rocket in cross-section

THE FUTURE OF SPACE TRANSPORT TECHNOLOGY

If humans are to visit other bodies in our solar system, technology still has a long way to advance. Ion drives and solar sails are two new devices being considered for propelling spacecraft between the planets.

Ion Drives

Ion drives are engines that use xenon gas instead of chemical fuels. In the spacecraft engine, the xenon is electrically charged, accelerated, and then emitted as exhaust. This action pushes the spacecraft in the direction opposite to the emission.

The thrust generated by an ion drive is 10 000 times weaker than the thrust achieved by today's chemically fuelled rocket engines. Can you feel the force created by the page of this textbook resting on your hand? That force is roughly equal to the force an ion drive would exert against your hand. However, the thrust from an ion drive lasts an extremely long time. In space, that little bit of force applied over a long period of time results in a very fast vehicle. For great distances, the amount of fuel required is about 1/10 of what would be used by a typical spacecraft.

reSEARCH

It's Always Sunny— Above the Clouds

In August 2001, NASA launched *Helios*, the first remotely piloted, solar-powered "flying wing" that can fly more than 30 000 m above Earth. Find out more about the design of the craft, the science behind the design, and how NASA hopes to apply the technology to explore space. Begin your search at www.pearsoned.ca/scienceinaction.

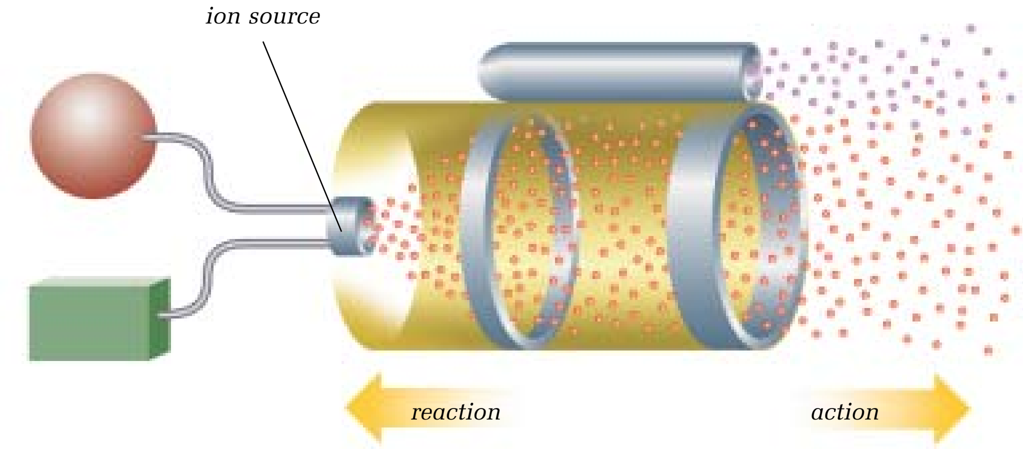

Figure 2.9 Ion drives may be an option for powering spacecraft that could take the first astronauts to Mars. Imagine a car getting about 19 000 km/L of fuel. That is the potential benefit of an ion drive.

Solar Sails

The idea of propelling spacecraft using solar sails is similar to the idea of propelling boats using wind sails. Instead of harnessing air currents for energy, solar sails would use the Sun's light. The Sun emits electromagnetic energy in the form of photons. The solar sails being tested are made of carbon fibre. When the photons hit the sail, the energy transmitted causes the spacecraft to move. Proposals for solar sails suggest that they might be made from material that could be spread as thin as plastic wrap and extend over 400 m^2. Use of solar sails is expected by 2015.

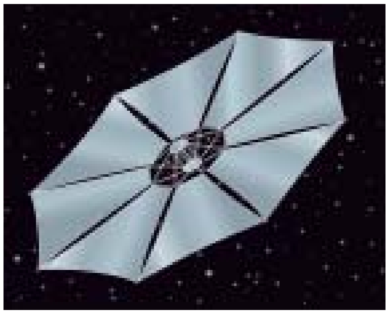

Figure 2.10 Some scientists estimate that a spacecraft powered by solar sails could travel about 5 times as fast as a current spacecraft.

ACTIVITY E-3

Problem Solving

DESIGNING A SOLAR SAIL-POWERED SPACECRAFT

Materials & Equipment

- for the sail: a variety of materials (such as thin cloth, paper, plastic wrap, wax paper, aluminum foil)
- for the wheels: a variety of pieces of cardboard of varying thickness
- scissors
- for the spacecraft body: small piece of wood (about 10 cm long, 3 cm wide, 1.5 cm thick)
- thumbtacks
- small gauge, rigid wire
- masking tape
- washer (about the diameter of a quarter)
- electric fan
- stopwatch

Recognize a Need

The solar sail holds great promise for interplanetary flight. With the Sun as an energy source, the potential for economical power seems limitless. Yet, what is the best design for such a sail? Logically, one might think that the larger the sail, the faster and farther a craft could go. In this activity, you will learn that many details must be considered in designing any spacecraft.

Note that in this activity you will be simulating solar power and its effects on the design of solar sails. Instead of using the Sun's light to power your craft, you will be using wind currents.

The Problem

With the materials provided, you are to design a sunlight-powered spacecraft that will take a specified payload (the washer) to a set destination. The craft must be able to travel straight to hit its destination, make the trip in the shortest time possible, and arrive at the destination with the payload intact.

Criteria for Success

- Produce a set of scale drawings of your craft and label them. Briefly describe the scientific principles met by your design, and justify the choices you made.
- Use simple materials to build a functioning model spacecraft powered by a sail. The craft must be able to travel the minimum design distance to the destination, without dropping its payload.

Brainstorm Ideas

1 Working in a small group (your "design team"), discuss which of the materials you have available would be most suitable for a solar sail.

2 Consider the options for the overall design of the craft, including: size of the body; size, thickness, and position of the wheels; size and shape of the sail; and position of the payload.

3 Make a labelled sketch of your proposed model before you build it; modify the design if necessary.

Build a Prototype

4 Cut the wheels from the cardboard provided.

5 Use the thumbtacks to fasten the wheels to the piece of wood.

6 Cut the sail from the material of your choice.

7 Use the wire to form a support, or mast, for the sail. Tape the end of the wire to the wood.

8 Tape the washer to the wood as your payload.

Test and Evaluate

9 Perform a preliminary test on your spacecraft by blowing on the sail. (No testing is to be done with the fan yet.) Adjust your design as necessary.

10 Predict how far your spacecraft will travel in your official test.

11 After all modifications have been made, run the official test on a smooth, hard surface.

12 Place your model at the designated starting position, with the target destination (about 1 m wide) 2 m away. Set the fan on the floor, about 30 cm behind the craft. *Note: Be careful when using an electric fan.*

13 As soon as you release the craft, start the stopwatch to time the journey to the target. Repeat your test three or four times and calculate the average speed.

14 Now, without a fixed destination, test the maximum distance your craft will travel.

Communicate

15 Write a brief summary describing the relationship between the speed of your spacecraft and: (i) the size of the sail; (ii) the size of the wheels; and (iii) the material of the sail. Also explain how the position of the payload affected the balance and speed of your craft.

16 What problems did you experience with your prototype? Explain how you might correct these, and invite suggestions from other design teams.

17 Was the maximum distance you predicted your craft could travel close to the actual distance you found in your test? Explain how you arrived at your prediction and why your model performed or did not perform as predicted.

18 In which ways does your model operate like a solar sail? In which ways does it not?

Figure 2.11 Brainstorm ideas and build a prototype.

SHUTTLES, SPACE PROBES, AND SPACE STATIONS

In the decades since the first simple satellites, the science of rocketry has sent humans on round-trips to the Moon and sent robots to investigate our neighbouring planets. It has also launched the Hubble Space Telescope to let us look far out into the universe and back in time to the birth of the universe—generally thought now to be some 12 to 15 billion years ago.

There are three main types of spacecraft in use. Shuttles transport personnel and equipment to orbiting spacecraft. Space probes contain instrumentation for carrying out robotic exploration of space. (These are described in more detail in section 3.2.) Space stations are orbiting spacecraft that have living quarters, work areas, and all the support systems needed to allow people to live and work in space for extended periods.

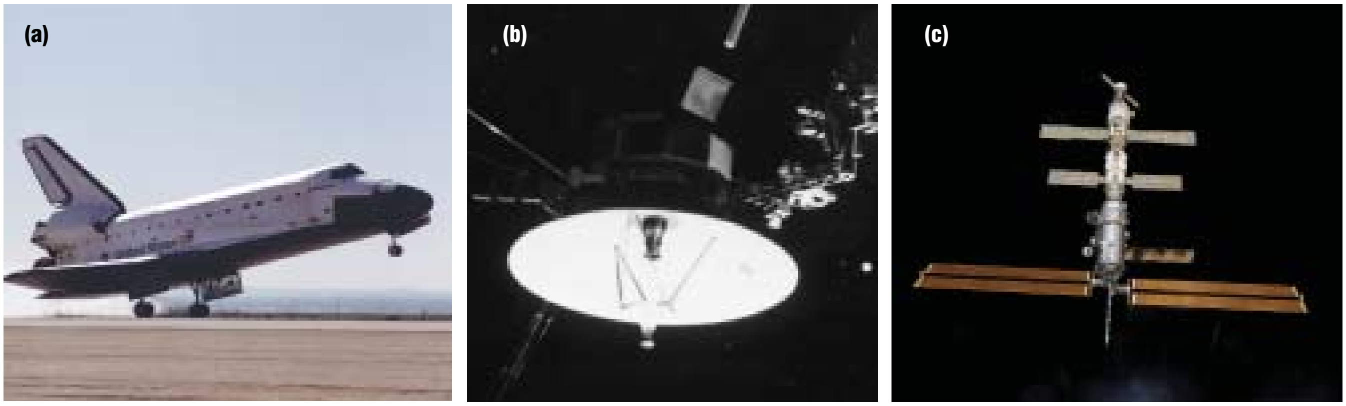

Figure 2.12(a) American space shuttle, **(b)** *Voyager* space probe, and **(c)** International space station

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Ticket to the Moon

A Japanese company is already taking reservations for trips to the Moon in 2010. In a recent North American survey, more than 60% of the people who responded said they would like to take a vacation in space. Of those people, most said they would not hesitate to spend three months' pay for a two-week vacation off the planet.

THE NEXT STEP

A manned interplanetary space journey would be much easier if the spacecraft did not not have to begin by fighting Earth's gravity or travelling through its atmosphere. Scientists believe that the best place to start an interplanetary flight is from an orbiting space station or even from the Moon.

The International Space Station, orbiting Earth at an altitude of 350 km, provides such a place. It is a joint project of 16 nations, including the United States, Canada, Japan, Russia, Brazil, and 11 nations of the European Space Agency. The station will serve as a permanent laboratory in space, as well as a command post for building and launching interplanetary rockets. Construction of the International Space Station is well under way, with modules (subsections of the craft) being made and sent up from Earth. When it is completed, it will have a living and working space equal to the size of three average-sized Canadian houses.

Almost certainly, more space stations will be established in the future. As well, several private companies are planning to develop hotels and amusement parks in space or on the Moon.

Figure 2.13 Humans are ready for the next step in leaving Earth and living for extended times in space.

CHECK AND REFLECT

Key Concept Review

1. Archytas's model pigeon is the first rocket ever recorded. What method did he use to propel his pigeon?

2. Who were the first people to use gunpowder to propel arrows with the aid of rockets, and when?

3. Which was the first country to launch an artificial satellite?

4. Describe the three basic parts of a rocket, and draw and label a sketch showing the parts.

5. Name two alternatives to rocket engines that scientists are studying as a means of propelling spacecraft on long journeys.

Connect Your Understanding

6. Explain what would happen if a rocket's payload were greater than the allowed percentage.

7. What is the main attraction for using an ion drive for powering spacecraft?

8. Besides savings in fuel costs, what is the other main advantage to using a solar sail?

Extend Your Understanding

9. The force of gravity on the moon is 1/6th of that on Earth. Imagine you had a summer job as a chef's assistant at a hotel on the Moon. Describe the challenges you would face doing each of the following activities inside the hotel, and how you would overcome those challenges.
   a) washing dishes
   b) cooking pancakes
   c) climbing stairs
   d) having a swim in a pool

10. Imagine a luxury hotel located on the bright side of the Moon. Describe three hazards that might face a structure located there.

11. Every planet in our solar system except Pluto has been explored either remotely (by probe) or on its surface (with a microwave oven-sized robotic "lander"). Research the technology that has been used to study each planet, and investigate why a space probe has not yet been sent to Pluto.

2.2 Surviving There: Technologies for Living in Space

Only a thin atmosphere encircling our planet holds all we need for life on Earth. Outside that bubble is the "cold vacuum of space" that Canadian astronaut Roberta Bondar referred to in the introduction to this section. It is an environment that is hostile to human life in numerous ways.

Figure 2.14 Canadian astronaut Julie Payette played an active role in assembling the International Space Station.

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All-Occasion Pen
NASA spent close to $2 million designing a pen that would work in space. It had to be able to write in a vacuum, upside down in microgravity conditions, and in temperatures that range from +200°C in full sun to -200°C in the shade.

GIVE IT A TRY

SHARING A SMALL PLACE IN SPACE

Using a piece of cord 16 m long, lay out a square on the floor that measures 4 m × 4 m. Imagine that this outlines the size of the spacecraft that will be your home for 12 months during a trip to Mars.

Stand in the square with five other classmates. For about 1 min, move around with your fellow astronauts as best you can in the space provided.

Return to your desks and, with your group, think about all the problems that could arise during a long trip in this type of confinement. Some of the aspects to consider include work space, room for exercise, and issues of privacy. In your notebook, list all the potential problems you identify. Beside each problem, write a solution that you and your group can suggest. When you are finished, compare the problems and solutions you identified with those that other groups noted.

HAZARDS OF LIVING IN SPACE

People travelling and working in space do not need an Earth-like environment simply for comfort. It is a matter of survival. Humans have orbited Earth, flown far into space, landed on the Moon, and returned safely to our planet. We are now aiming to put a human—not just a robotic machine—on another planet for the first time. Scientists believe we now have the technology to send a group of astronauts to Mars and back. This will not be a typical week-long mission for space shuttle astronauts, nor will it be a few months as experienced by astronauts in the International Space Station. Astronauts going to Mars will be gone for two to three years.

Environmental Hazards

Space is a vacuum, with no air or water. It also contains many hazards for the spacecraft and its occupants, including the damaging effects of cosmic rays and solar radiation and the risk of being hit by meteoroids. There is no atmosphere so temperatures can range from unimaginably cold in shadows to extremely hot in the full sun. The gases in the atmosphere that keep us alive on Earth do not exist in space. Neither does the pressure of the atmosphere, which helps regulate our heartbeats.

Psychological Challenges to Confined Living

Long trips in a confined living space may also lead to psychological problems. Imagine spending every minute of every day with one person for two years. Now imagine spending that two years in an enclosure not much bigger than your classroom. Stepping outside for a breath of fresh air is strictly prohibited!

Figure 2.15 The space in which astronauts live and work is extremely cramped.

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Record-Holder for Space Living

In 1995, Valery Polyakov, a Russian cosmonaut (the Russian term for astronaut) returned to Earth after living for a record 437 days in space. He suffered loss of bone mass, but by exercising strenuously for two hours every day, he stayed physically fit and was able to walk away from his spacecraft unassisted after he arrived back on Earth.

The Body and Microgravity

Before astronauts can travel to distant planets in our solar system, there is much to be learned about how the human body adapts physically to living in space. A particular problem is living in **microgravity**. Recall from earlier studies that **gravity** is the force of attraction between masses. On Earth, gravity gives us our feeling of weight. Microgravity is the condition in which the gravitational forces that act on mass are greatly reduced. For example, a person would weigh only one-third on Mars of what he or she would weigh on Earth. That's because on Mars the force of gravity is weaker (only one-third) than on Earth. In space, that person is almost completely weightless, as are the spacecraft and all of its contents.

In conditions of weightlessness, the body undergoes many changes. Bones have much less pressure on them than normal and so they expand. The heart does not have to pump as hard to circulate blood. Muscles used for walking and lifting do not get used as much, and therefore weaken. Even a person's visual depth perception is affected. These and other concerns will be extensively studied on the International Space Station in preparation for interplanetary travel.

Figure 2.16 There are several problems for the human body when it has been in space for long periods of time. Bones lose their calcium and become more brittle. Muscle mass starts shrinking. Exercising in space helps keep the muscles fit.

THE SPACE SUIT

When walking or working outdoors on Earth, we usually try to dress appropriately for the conditions, wearing a warm jacket if it is cold and rain gear if it is wet. When taking a walk in space, however, we would be faced with a more difficult environment. Once astronauts leave their spacecraft, everything they need to survive must be brought with them: air, water, a heating system, a cooling system—even a portable toilet.

In addition, the suit must be flexible enough to allow the astronaut to grasp a wrench or twist a bolt. Each space suit is custom-designed for the man or woman who will wear it, from the size of the shoes to the size of the gloves.

Figure 2.17 A space suit is a mini-Earth system that allows the wearer to work freely outside the spacecraft. The *Apollo* suits cost about $400 000 (U.S.) each. Today's space suits cost about $20 000 (U.S.).

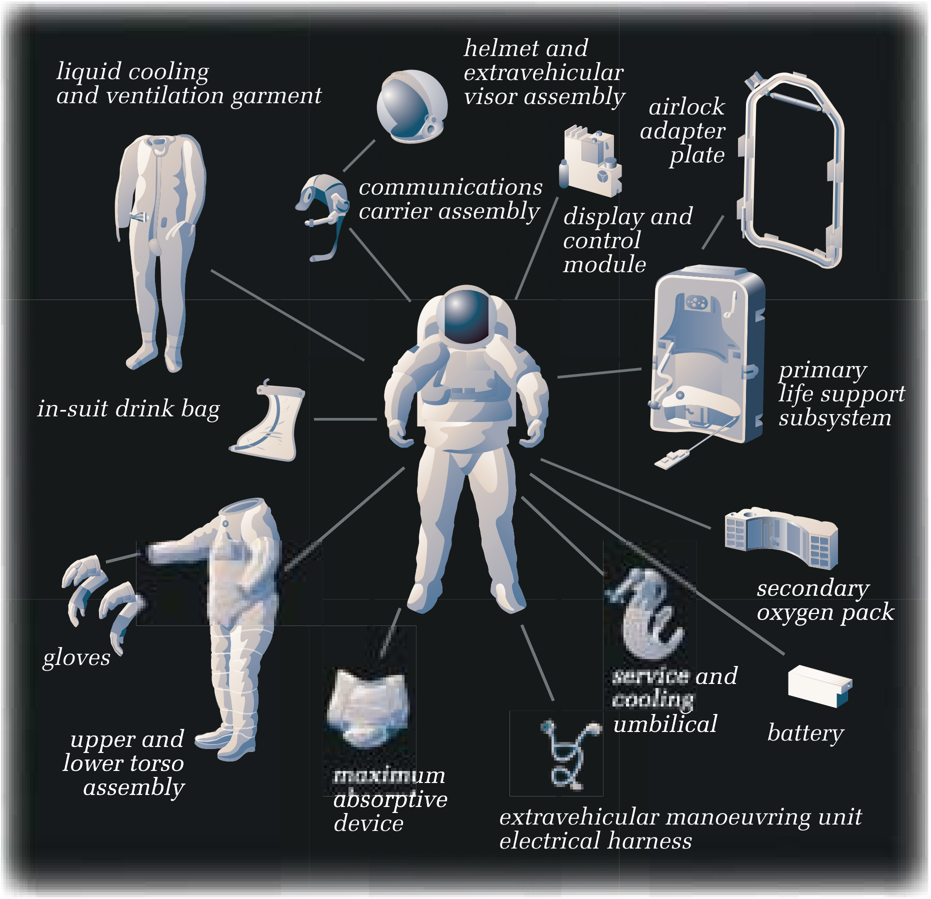


Figure 2.18 The first astronauts to walk in space were connected to their spacecraft with a hose that supplied oxygen and a means of communication. Modern astronauts use a suit that is completely self-contained, enabling them to work outside their crafts for up to 9 h at a time.

A HOME IN SPACE

Outside Earth's atmosphere, none of the life-support systems that humans must have for survival exist. If people are planning to move out to space colonies in the coming years, their space station homes will have to come with several important features. First, clean water, breathable air, and comfortable temperatures and air pressure must be provided. As well, the station must carry its own source of power to provide the energy necessary to run the life-support systems and other equipment at all times.

Recycling Water

The International Space Station will be using devices that can recycle almost 100% of the water in the station. This includes waste water, water used for hygiene, and moisture in the air. Careful recycling of water on the space station will keep a crew of seven comfortable for several months.

reSEARCH

Technology for Life

Choose one of the technologies necessary for providing life support to humans during space travel and research the history of its development. Begin your search at www.pearsoned.ca/scienceinaction.

Recycling is also essential in the day-to-day life in a space station. Because there is so little room for storage, as much of the materials carried as possible must be recyclable or reuseable. Consider, for example, the challenge of how best to use the limited supply of water carried in a spacecraft. Researchers have developed the technology to filter, purify, and recycle the same water again and again on long space flights. This technology is now also being used on Earth to provide environmentally safe sewage treatment for houses.

On the International Space Station, the Environmental Control and Life Support Systems are designed to ensure life support. The functions of the life-support system include:

- recycling wastewater (including urine) to produce drinking water;
- using recycled water to produce oxygen;
- removing carbon dioxide from the air;
- filtering micro-organisms and dust from the air; and
- keeping the air pressure, temperature, and humidity (air moisture) stable.

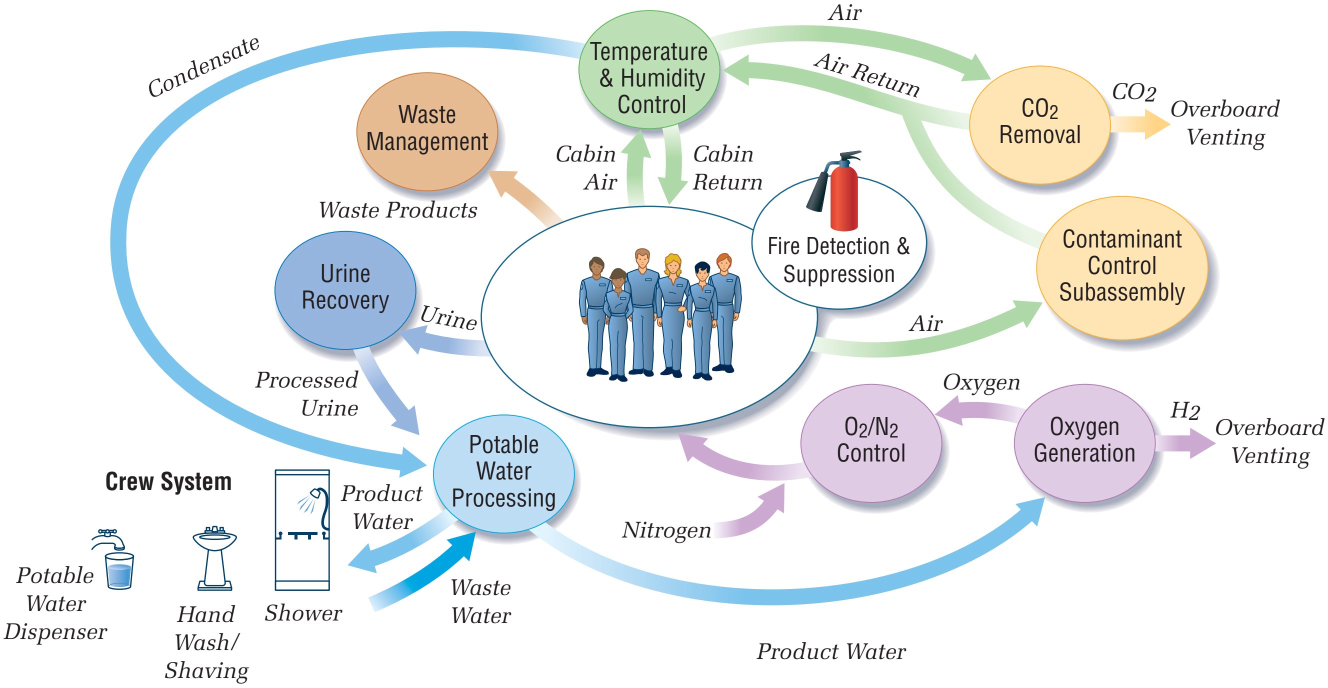


Figure 2.19 The water recycling system aboard the International Space Station

Producing Oxygen

Scientists have also come up with a simple but effective way of producing oxygen in space. As you may recall from past studies, the process of electrolysis uses electricity to split water molecules into their component elements: hydrogen and oxygen. Applied in a spacecraft, this process can supply most of the oxygen a crew needs. The hydrogen is vented into space.

ACTIVITY E-4

Experiment **on your own**

DESIGNING AND BUILDING A WATER FILTER

Before You Start

There are many challenges to living in space. One is how to maintain a good supply of useable water for drinking, washing, and other activities. As humans plan ever-longer space voyages, the need for safe recycling of the precious water carried on a spacecraft or space station becomes of the utmost importance.

In this activity, you will investigate how well different materials filter water. You may wish to use Toolbox 2: The Inquiry Process of Science to help you plan your experiment.

The Question

How effective are various materials for filtering water and improving its clarity?

Design and Conduct Your Experiment

1. Write a hypothesis about which common substances (such as pea gravel, sand, cotton balls, and charcoal chips) would make suitable materials for a water filter.
2. Decide which materials and equipment you will need to test your hypothesis. For example:
   a) What types of filtering materials will you use?
   b) What will you use as the main part of the filter to contain the filtering materials?
   c) What type of material are you attempting to filter out of the water?
3. Plan your procedure. For example:
   a) What evidence would you get from your experiment that would prove your hypothesis? How will you know your filter worked?
   b) What are the manipulated, responding, and control variables?
   c) What steps will you take to produce the data you need?
   d) How will you collect and organize the materials and observation data you collect for each trial?
   e) How will you assess the effectiveness of the different filtrates?

Figure 2.20 Planning your procedure

4. Write up your procedure and include a design. You may wish to use Toolbox 8: Diagrams to Help with the Design. Ask your teacher to approve the procedure before you begin.
5. Conduct your experiment.
6. Compare your results with your hypothesis. How accurate was your hypothesis? If your findings did not support your hypothesis, suggest reasons why.
7. Share and compare your procedure, set-up, and results with those of your classmates. How do the results compare? Is there anything you could do to improve on the design of your experiment?
8. What type of controls did you use to ensure that your data was valid?

Caution!
Do not drink or taste any of the water samples.

ACTIVITY E-5

Problem Solving

SPACE STATION DESIGN: THE VALUE OF TEAMWORK

Recognize a Need

To design an orbiting space station requires millions of dollars. To transport the materials into space and construct such a station requires billions of dollars. No country can afford to build a space station on its own. A better idea is a cooperative team effort, one that uses a great variety of expertise and shares the costs.

The Problem

You and two or three other classmates represent a country that has been assigned the task of designing a module for the new *Pangea* space station. First, you will work with all the other teams (as a class) to design a space station for a crew of 20 men and women. Then, your team will design and build a model of one of the modules of *Pangea*.

Criteria for Success

To be successful, the final assembled space station must (1) show close fit and (2) match the original plan agreed to by all teams.

Brainstorm Ideas

1 As a class, brainstorm ideas for how many and what type of modules the new space station needs. Agree on an overall plan and make a general sketch of it.

2 Organize into small groups, each representing the design team for a country. (The number of groups depends on the number of modules chosen in Step 1.) Your teacher will randomly assign a module to each group. With your team, brainstorm ideas for your module, keeping in mind the criteria for success.

Build a Prototype

3 Using your choice of box, cardboard, and small household items, construct your scale model. Label the parts clearly.

Test and Evaluate

4 Present your module on the due date set by your teacher. This should be the first time that teams see the other models.

5 Connect the modules on a large table or on the floor, using the original sketch for the space station as a guide.

6 Evaluate the results. How well does the final space station match the original plan? Are the modules to the same scale? Do they fit together well?

Communicate

7 As a class, discuss problems that arose during module construction. In a brief written summary, make recommendations about how the design and construction process for the space station model could be improved.

8 Think about how cooperating countries must overcome problems in building a space station together. Brainstorm a list of ways that communication is achieved.

Materials & Equipment

- box (shoe box or similar)
- pieces of cardboard
- a variety of small household items (film canisters, match boxes, wire, toothpicks, etc.)
- scissors
- tape
- glue

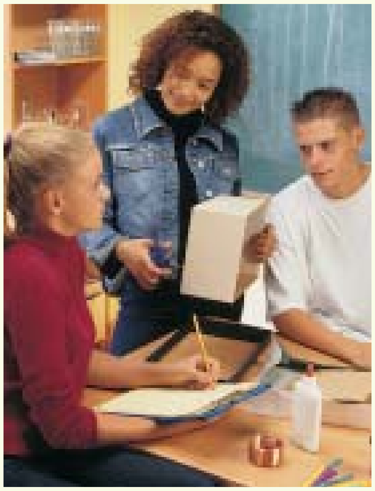


Figure 2.21 Step 2

CHECK AND REFLECT

Key Concept Review

1. Briefly describe how working on the International Space Station might affect a person psychologically.
2. How does living in a microgravity environment for a long period of time affect the human body?
3. Why must a space suit be flexible?
4. How many people are there in a typical crew on the International Space Station?

Connect Your Understanding

5. Name four necessities of an astronaut, in order to work outside a spacecraft.
6. Explain why a regular ballpoint pen will not work in space.
7. What problems do astronauts encounter when trying to eat and swallow their food?

Extend Your Understanding

8. The following table shows the problems that the human body encounters when it is in space for a long time. Copy the table into your notebook and write a recommended solution to each problem. This may require some out of class research.

Problems of Living in Space	Recommendations
1. Loss of body mass	
2. Decrease in the production of red blood cells	
3. Loss of bone mass and density	
4. Loss of calcium, electrolytes, and plasma with excretion of body fluids	
5. Loneliness, isolation, depression	

9. Imagine you were going to spend 3 months in the International Space Station. Make a list of all the items you would like to bring for recreation during that period. Remember the storage and mass limitations.
10. Adjust your list in question 9 so that the total mass of the items equals 1 kg (your allowed limit). Explain which item is the most important item to you and why.

Careers and Profiles

ASTRONAUT

Few people have ever looked out a window and had a view of the entire country of Canada, from coast to coast to coast. One of those who has, however, is Dr. Roberta Bondar. In January 1992, Dr. Bondar became Canada's first female astronaut when she was assigned to be a payload specialist on NASA's shuttle flight STS-42.

Dr. Bondar grew up in Sault Ste. Marie, Ontario. From the time she was eight years old, she was fascinated with building model rockets, space stations, and satellites, and inspired by the idea of exploring space. As she grew up, her interest in space research increased. Pursuing her dream of a career in the area meant choosing a field of study that she thought would be valuable in space research. She turned to medicine, specializing in neurology, the study of the nervous system.

Also important in helping her succeed in her chosen career have been Dr. Bondar's many non-academic interests. She has a pilot's license and is an accomplished photographer. She also enjoys exploring the outdoors. Anyone thinking of pursuing a career in space research and exploration, she says, should develop a wide variety of interests related to his or her goals.

Dr. Bondar identifies three main characteristics of a good astronaut. First is self-discipline. The second is the ability to be team player. Third is the ability to work alone. Good astronauts must have confidence in their own abilities and be able to contribute to the entire team.

What does Dr. Bondar see for the future of Canadians in the space exploration field? For one, she predicts more technological breakthroughs such as RADARSAT, which will provide us with increasing information about how our world is changing. She also points to expected advancements in communications and global positioning hardware. Canadian astronomers, she adds, continue to be at the forefront of new discoveries. While astronauts tend to get a great deal of media attention, Dr. Bondar emphasizes that it is the technical staff, researchers, development engineers, and astronomers who are "pushing the envelope" in space discoveries.

Figure 2.22 Dr. Roberta Bondar

Dr. Bondar offers the following advice for students interested in becoming involved in the space field. Keep your focus, develop a wide range of interests, and never lose your sense of wonder and curiosity. Start by being explorers of your own planet. Learn as much as possible about the great diversity Earth has to offer. In this way, even if you never go into space yourself, you will start to see and appreciate our planet in a new light.

1. Why should a person who is interested in becoming an astronaut have a wide variety of interests related to that goal?
2. Why do you think it is important for astronauts to be good team players, as well as being able to work on their own?
3. What do you think would be the most interesting part of being an astronaut?

2.3 Using Space Technology to Meet Human Needs on Earth

Although we may not realize it, our daily lives are full of products and systems that were first developed for exploring space. From instant powdered juice drinks and top-of-the-line sports equipment, to satellites that allow us to talk to friends who live far away, we rely on "space age" technology in many ways.

SATELLITES

Satellites—sometimes referred to as "artificial satellites"—are objects that are built and sent into Earth's orbit by humans. (A "natural" satellite refers to any small body that orbits a larger body, such as a moon orbiting a planet.) Looking like small spherical containers or snap-together toy structures, these relatively small objects are loaded with electronic equipment, digital imaging apparatus, and other instrumentation. They transmit the information they receive to ground stations by radio waves, a topic you will learn more about in Section 3.0.

Satellites play a major role in our lives, performing a variety of functions from space. They can help us communicate, observe and forecast weather, predict magnetic storms, and even find our location on the planet. We send satellites into space to allow us to watch television and make long-distance phone calls. Some newer cars even come equipped with satellite tracking devices. Computers in these cars receive satellite signals. This information is then relayed to the driver as directions to the nearest gas station or a particular address.

*info***BIT**

High Spy

Some military and national defense satellites conduct surveillance from hundreds of kilometres above Earth. The cameras on these satellites are so sensitive that they can see you play tennis, and even tell what brand of tennis ball you are using!

Figure 2.23 Satellite technology can help drivers in unfamiliar cities find their way around.

Putting satellites into orbit outside Earth's atmosphere was an important step in the history of space exploration. Their use continues to lead to advances in both our scientific understanding of space and the development of further space-related technology.

QUICKLAB

DATA RELAY FROM SPACE TO EARTH

Most data received from research satellites are relayed to stations on Earth through a network of satellites and ground-based receivers. The information, received as signals, must be decoded and then transmitted to the user through communication networks. In this activity, an imaginary NASA satellite named SNIFF (SuperNova Infrared Fact Finder) collects data about a supernova and transmits the data—through a series of relay points—to a scientist working at the University of Alberta.

Purpose

To simulate how data are transmitted from space to someone on Earth, and to show some problems that must be overcome to make such transmissions successful

Procedure

① Your teacher will assign roles to eight students, as listed on the right.

② In a large space, the eight students should arrange themselves according to the pattern shown in the diagram. The rest of the class will be observers.

③ Students in roles 4, 6, 7, and 8 stand in a small circle, facing out. They represent the four relay positions on Earth. In unison, they will revolve counterclockwise very slowly to represent the spinning Earth.

④ Students in roles 3 and 5 are satellites in geosynchronous orbit, which means they must move in time with Earth's rotation.

⑤ The SNIFF satellite (role 2) lies at low altitude and orbits Earth about 15 times a day. The student in this role should walk at a quick pace around Earth, about 2 m away. The student should complete several orbits for every one rotation of Earth. The supernova (role 1) should be a fair distance away and not moving.

⑥ The ball represents the data (in this case, light) being picked up from the star by SNIFF. When students are in position and moving, data transmission can start. The supernova tosses the ball to SNIFF. SNIFF sends the ball to the DRS. The DRS sends the ball to ground station #1. Ground station #1 sends the ball to the communication satellite, who then sends it to ground station #2 in Calgary. Ground station #2 hands the ball to the University of Alberta in Edmonton (simulating a land-line telephone/Internet connection). Finally, the University hands the ball to the scientist (simulating a computer network connection).

⑦ Repeat the relay two or three times. Observe what happens.

Questions

8 What conditions are necessary for SNIFF to be able to communicate with the relay satellite?

9 What would make this type of satellite communication easier and more dependable?

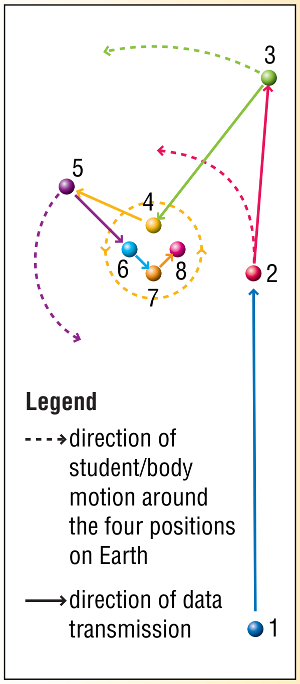
10 With reference to the simulation, describe what problems must be overcome in transmitting data from space to a specific location on Earth.

Materials & Equipment

- a small rubber ball (about 15 cm diameter)

Student Roles

1. a supernova
2. the SNIFF satellite
3. the Data Relay satellite (DRS)
4. ground station #1
5. a communication satellite
6. ground station #2
7. the University of Alberta
8. a scientist



(Adapted from EUVE Dataflow Demo, UC Berkeley and NASA)

Communication Satellites

In the early part of the 20th century, telegraph and telephone communication across the North American continent travelled through wires. Cable connections needed to be physically in place in order for one person to talk with another. This was a difficult and expensive process even on land. Setting up telephone communication with someone across an ocean was a much greater challenge that required the laying of submarine cables. Communication satellites have eliminated the need for costly cable laying.

Today, satellites use digital systems that result in clearer transmissions and allow for a great number of users at any one time. Every nation in the world now employs "wireless" technologies for a wide range of communications.

Figure 2.24 Launched in 1972, Telesat Canada's *Anik 1* provided Canada with communication across the entire continent. Canada was also the first country in the world to use satellites to transmit television broadcasts.

Satellites for Observation and Research

Satellites are invaluable tools for monitoring and forecasting weather. Weather satellites are designed to stay in one position above Earth. This is called a *geosynchronous orbit*, which means that the satellite moves at the same rate as Earth spins. In this way the satellite can observe the same area at all times. The result is 24-hour-a-day monitoring of weather conditions.

Observation satellites can do more than just take photographs and monitor weather. Two Canadian satellites, LANDSAT and RADARSAT, have been used to follow ships at sea, monitor soil quality, track forest fires, report on environmental change, and search for natural resources. RADARSAT sees more than 1 000 000 km^2 of Earth in each of its orbits. These satellites are not in geosynchronous orbit.

Figure 2.25 A weather satellite being launched into orbit from the space shuttle

Remote Sensing

The main purpose of satellites in low Earth orbit (at 200 to 1000 km altitude) is to carry out remote sensing. Remote sensing is a process in which imaging devices in a satellite make observations of Earth's surface and send this information back to Earth. Images can be photographs taken by cameras or data collected from the sensing of heat and other invisible energy waves. Remote sensing can provide information on the condition of the environment on Earth, natural resources, and effects of urbanization. This information is used for planning.

Figure 2.26 Satellite picture of weather over southern Manitoba

Satellites as Personal Tracking Devices

Imagine always knowing your position on the planet, accurate to within a few metres. The Global Positioning System (GPS) lets you do just that. This technology was designed to give people, wherever they are, their location on the ground at any time. Twenty-four GPS satellites are in orbit around Earth, which means that at least three are above any given location in the world at any given moment. Radio signals from the satellites are picked up by a hand-held receiver (which is about the size of a small hand-held video game). The signals are translated by a computer in the receiver, which then shows on a digital display the operator's position in relation to the satellites.

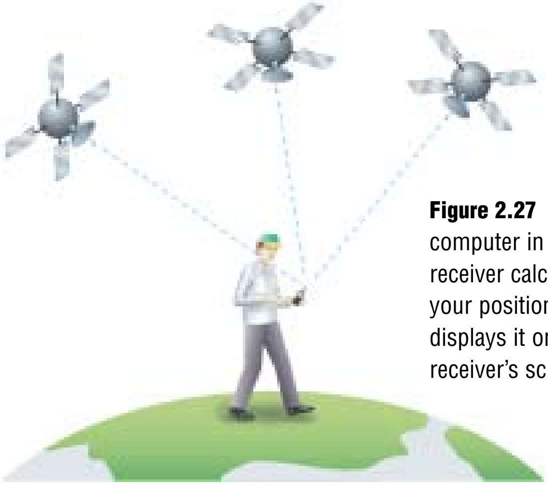


Figure 2.27 The computer in a GPS receiver calculates your position and displays it on the receiver's screen.

Figure 2.28 With 24 satellites in orbit, there are at least three above the horizon, relative to a person's location on Earth, at any one time.

SKILL PRACTICE

ON LOCATION WITH GPS

This activity illustrates in a two-dimensional way how the Global Positioning System uses satellite signals to determine the position of someone holding a GPS receiver. You will need a pencil and a geometry compass.

1. Your teacher will give you an enlarged copy of the map shown here . Imagine that you are standing in a location somewhere on this map when you turn on your GPS receiver.
2. Satellite 1 transmits a radio signal to the receiver in your hand and the GPS device calculates that you are 1000 km from the satellite. Using the compass, measure 1000 km on the scale provided.
3. Next, place the compass point on the position labelled Satellite 1 and draw a circle that has a radius equal to the distance from the satellite.
4. Repeat steps 2 and 3 for Satellites 2 and 3, using the information in the table.
5. The spot where all three circles meet on the map indicates your position on the ground.
6. Suggest how satellites know where their position is in relation to Earth.

Satellite	Distance to GPS Receiver
1	1000 km
2	300 km
3	940 km

“Space Age” Inspired Materials and Systems

Many items, materials, and systems originally designed for a space application have been put to practical use on Earth. Innovations to help us study our universe, travel out into it, or exist in the space environment can be found today in just about every aspect of our lives. The table below lists some of the spin-off applications of space technology.

Figure 2.29 Not all of the technology created for exploring or living in space is used only in space. The fire-resistant suits and compact breathing apparatus used today by firefighters are spin-offs from innovations developed for NASA astronauts.

Field	Space Use	Earth Use
Computer technology	• Structural analysis of spacecraft • Monitoring of air quality aboard spacecraft • Simulation of space environment for training	• Use of microelectronics in appliances and office equipment • Structural analysis of buildings, bridges, etc. • Analysis of smokestack emissions • Development of virtual reality software
Consumer technology	• Design of space food for astronauts on long flights • Study of aerodynamics and insulation	• Manufacture of enriched baby and freeze-dried foods • Design and manufacture of improved bike helmets, golf balls, running shoes, and ski goggles
Medical and health technology	• Design of electronics for the Hubble Space Telescope • Development of slow-release medication to control motion sickness • Design of microcircuitry for electronics • Development of communications and robotic systems	• Development of digital imaging for the detection and treatment of breast cancer • Manufacture of motion sickness medications • Development of a human tissue stimulator to control chronic pain • Development of voice-controlled wheelchairs
Industrial technology	• Development of microlasers for communication	• Application of microlasers for communication, and to cut and melt materials
Transportation technology	• Development of parachute material for the Viking space mission	• Improvement of traction on car winter tires
Public safety technology	• Development of computer robotics	• Design of emergency response robots for use in situations too dangerous for humans (e.g., to inspect explosive devices)

CHECK AND REFLECT

Key Concept Review

1. List three uses for satellites.
2. What does the abbreviation GPS stand for?
3. Name the satellite that Canada first launched to provide communications across the country. In what year was it launched?
4. What is remote sensing?
5. Some materials are referred to as “spin-offs” from space technology. What does that mean?

Connect Your Understanding

6. With GPS technology, why do you require at least three satellites to determine your position?
7. Do you agree or disagree with the statement “There is no location on Earth where GPS does not work”? Explain your answer.

Extend Your Understanding

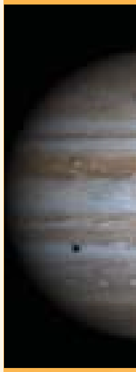
8. Study Figure 2.30, which shows a number of common spin-off objects whose origins lie in space technology. List six of the objects and the technology behind their development.

   Example: Airplane – satellite navigation and communication

Figure 2.30 Question 8

9. Consider a colony under the ocean where divers in deep-sea suits work on the ocean floor. Do you think that a GPS-like system for determining precise locations might work in this situation? Give reasons for your opinion.

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. What is the only planet in our solar system that has not been visited by a space probe? Why is that?
2. List the three main types of spacecraft currently being used.
3. In a rocket, what does “payload” usually refer to?
4. What limits how long an astronaut can stay out in space in his or her space suit?

Connect Your Understanding

5. Why were animals used in the first test flights of vehicles launched to orbit Earth?
6. Place the events listed below in the order in which they occurred:
   a) first rocket into space
   b) rockets used in World War II
   c) Chinese use rockets to launch arrows
   d) rockets send mobile probe to Mars as part of *Pathfinder* mission
   e) rockets send humans to Moon and back
   f) first satellite launched
7. Explain why a space suit must have both a heating unit and a cooling unit.

Extend Your Understanding

8. Why is it necessary to recycle almost all of the water used on a spacecraft such as the International Space Station?
9. Draw a concept map starting with the term “space exploration.” Use 10 other terms that you have learned in this unit to complete your map.

Focus On SCIENCE AND TECHNOLOGY

If humans are to travel great distances in space, problems must be solved and technologies developed through the collaboration of many countries. The International Space Station has only been made possible through the co-operation and technological expertise of countries from around the globe. Working with a partner or your class, consider the following questions:

1. Why is it essential that certain scientific principles be understood before a technological solution to a problem is developed?
2. Is it worthwhile for members of the scientific community to share information from their research? Explain your answer. Suggest an instance when not sharing scientific knowledge might be a good decision.
3. Can scientific knowledge and technology develop and advance without the sharing of knowledge?

3.0

Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

Key Concepts

In this section, you will learn about the following key concepts:

- technologies for space exploration and observation
- composition and characteristics of bodies in space
- communication technologies
- triangulation and parallax

Learning Outcomes

When you have completed this section, you will be able to:

- explain, in general terms, the operation of optical telescopes, including telescopes that are positioned in space environments
- explain the role of radio and optical telescopes in determining characteristics of stars and star systems
- describe and interpret, in general terms, the technologies used in global positioning systems and in remote sensing

About 170 000 years ago, a star in its last great gesture before dying exploded in a display a million times brighter than the Sun. The light generated did not reach Earth until 1987, where it was discovered by Canadian astronomer Ian Shelton, who was working in an observatory in Chile.

Just as the vast and seemingly limitless oceans beckoned the early maritime explorers, today the far reaches of the universe beckon modern adventurers. Although the mysteries of space have captivated human curiosity for thousands of years, it has been only in the past few decades that we have had the technology to give us access to places not on our home planet. Until it is physically possible for humans to travel to the "shores" of distant planets and galaxies, our technologies must be our eyes into the universe.

In this section, you will learn about the tools and technologies that are helping us solve the many puzzles of space. From Earth-based telescopes and Earth-orbit satellites, to sophisticated space probes that can cross vast distances and send images back to Earth, technology is letting us reach farther and farther out into space. The more we see, the more we learn.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Using Technology to See the Visible

Look up at a clear, cloudless night sky and with your unaided eyes you can see a few thousand stars. With binoculars, you would see thousands more. Use a telescope and millions of stars will be revealed. Use one of the most powerful telescopes available and billions of stars come into view. Telescopes allow us to see fainter and more distant objects in detail that cannot be detected by the unaided eye.

A number of different types of telescopes are described in this section. Each provides us with a variety of information about the objects that make up our universe.

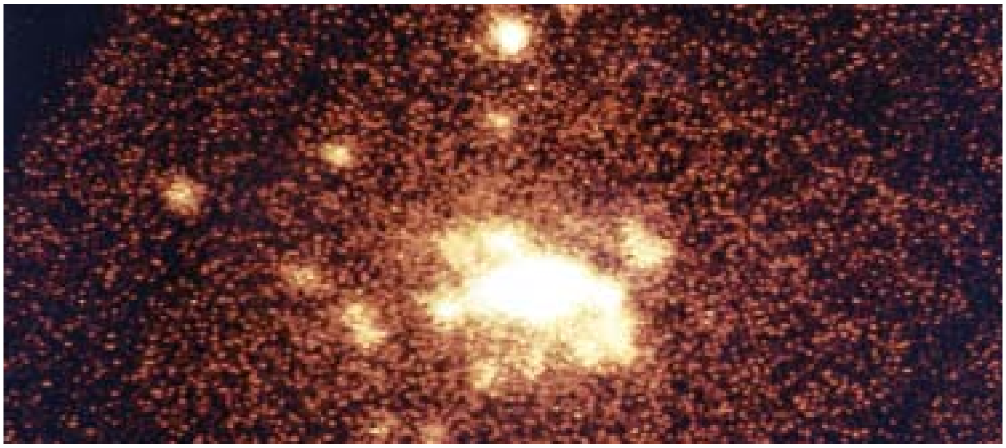


Figure 3.1 A highly magnified image of the Andromeda galaxy

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Magnificent Magnification
The first telescopes Galileo used had magnifications of only two or three. However, by making improvements to his lens-grinding and -polishing techniques, he was able to create lenses with longer focal lengths and so improve his telescopes' magnifications to 20 and 30 times.

SKILL **PRACTICE**

SHARPEN YOUR STAR-GAZING SKILLS

Pick a clear night on which to carry out this activity. All you will need is the cardboard tube from a roll of paper towel, a flashlight, a notepad, and a pencil. Here is a simple test of your observational skills.

Find a dark area away from house lights and street lights. (Make sure an adult knows where you are.) Wait a few minutes to let your eyes get used to the dark. Then focus your unaided eyes on a small portion of sky for about 1 min. Turn on the flashlight and write down your observations on the notepad.

When you are finished, turn off the flashlight and again let your eyes adjust to the dark. (If you put a red cellophane covering on the flashlight lens, your eyes will adjust more quickly.) Using the cardboard tube as a telescope, view the same patch of sky as you did before. What do you notice when you view the same area of sky using the cardboard tube?

Describe how the cardboard tube affected your observation, and explain why you think that happens.

OPTICAL TELESCOPES

Optical telescopes have been in use for the past 400 years. In 1608, a Dutch optician named Hans Lippershey made one of the first telescopes, but it is Galileo who has been credited with first using the telescope to study the visible features of the night sky.

Think of optical telescopes as "light collectors." That is what their series of lenses and mirrors do: gather and focus the light from stars so that we can see it. The larger the area of the lenses or mirrors in a telescope, the greater the ability of the telescope to see the faint light of objects that are very distant.

The first telescope ever designed was a simple **refracting telescope**. Refracting telescopes use two lenses to gather and focus starlight (see Figure 3.3). There is a limit to how large a refracting telescope can be. Any diameter over 1 m causes the glass in the lens to warp under its own weight. Trying to see through a lens when that happens would be like trying to make out details of the Moon by looking through the bottom of a pop bottle.

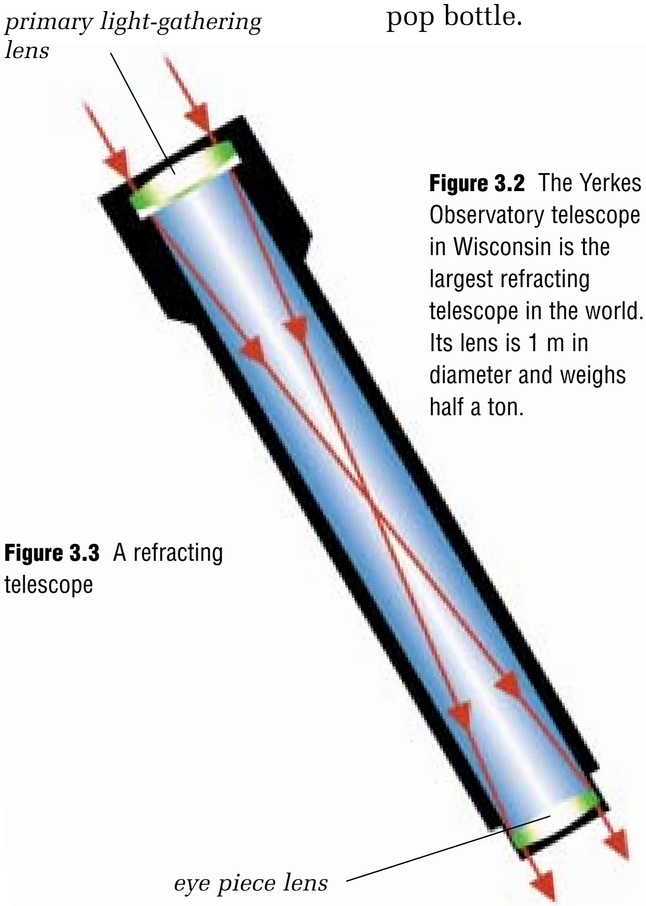

Figure 3.3 A refracting telescope

Figure 3.2 The Yerkes Observatory telescope in Wisconsin is the largest refracting telescope in the world. Its lens is 1 m in diameter and weighs half a ton.

Reflecting telescopes use mirrors instead of lenses to gather and focus the light from stars. At one end of a reflecting telescope is a large concave mirror, which is made from glass-like material that is coated with a thin layer of metal. The metal, such as aluminum, is polished to a shiny finish so that it can reflect the faintest light it receives.

Currently, telescope builders use a method called “spin casting” to form the largest mirrors. This process requires that molten glass be poured into a large spinning mould. Just as a rapidly turning amusement park ride swings its occupants outward, the spinning mould forces the melted glass to the mould’s outside edge. After the glass cools and solidifies, technicians grind it into the desired shape for the telescope. This process is quicker and less costly than previous methods of making mirrors. One of the largest reflecting mirrors created this way is 6 m in diameter, built by the former Soviet Union.

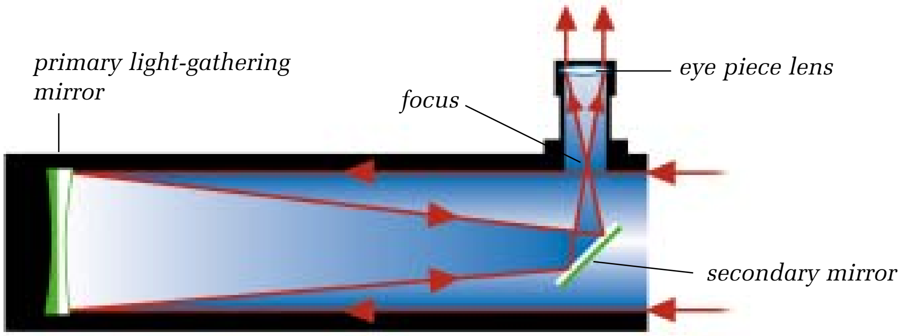

Figure 3.4 A reflecting telescope

Figure 3.5 The Canada-France-Hawaii Observatory, situated on Mauna Kea, Hawaii, operates a telescope with a 3.6-m mirror.

One of the newest innovations for ground-based optical reflecting telescopes is the use of segmented mirrors. A segmented-mirror telescope uses several lightweight segments to build one large mirror. The result is a large telescope with enormous light-gathering ability and resolving power (ability to distinguish details in an object). For example, each of the Keck I and Keck II telescopes atop Mauna Kea in Hawaii is 10 m in diameter, each made up 36 hexagonal mirrors.

INTERFEROMETRY: COMBINING TELESCOPES FOR GREATER POWER

The resolution of the images seen with optical telescopes can be further improved when two or more of the telescopes are used together. This technique of using telescopes in combination is known as **interferometry**. On top of Mauna Kea, Keck I and Keck II are located 85 m apart from each other. When working together, they can detect objects in space with better clarity and at greater distances than any other current Earth-based observatories can. Another example is the Very Large Telescope of the European Southern Observatory, located high in the Andean Mountains in Chile. It is really four separate telescopes being used together. Astronomers are able to obtain much more detail in the images they collect by using interferometry than by using a single telescope.

Figure 3.6 One of the Keck Observatory’s two telescopes, showing its 10-m mirror made of 36 hexagonal mirrors

*re*SEARCH

Hubble Insights

New discoveries about the universe are constantly being made with advances in technology. Search the Internet for the latest images from the Hubble Space Telescope. Explore how new information has changed our ideas about the universe. Begin your search at www.pearsoned.ca/scienceinaction.

THE HUBBLE SPACE TELESCOPE

Although remote mountains make excellent sites for building and operating telescopes away from light pollution and air pollution, astronomers are still at the mercy of the weather. Clouds, humidity (moisture in the air), and even high winds can interfere with star-gazing. The development of the **Hubble Space Telescope** offers a solution to these problems. Orbiting about 600 km above Earth, the Hubble Space Telescope (a reflecting telescope) uses a series of mirrors to focus light from extremely distant objects. Launched in 1990, the Hubble is cylinder-shaped, just over 13 m in length and 4.3 m in diameter at its widest point. It is modular in design. This allows shuttle mission astronauts to replace faulty or out-of-date instruments on the telescope without having to interrupt its other operations.

Each orbit that the Hubble makes around Earth takes about 95 min. While the telescope works 24 h a day, not all of that time is spent observing and sending data to Earth. Some time also goes to activities such as turning the telescope to focus on a new object of interest or switching data transmission modes. Commands for these tasks are sent from ground control several times a day.

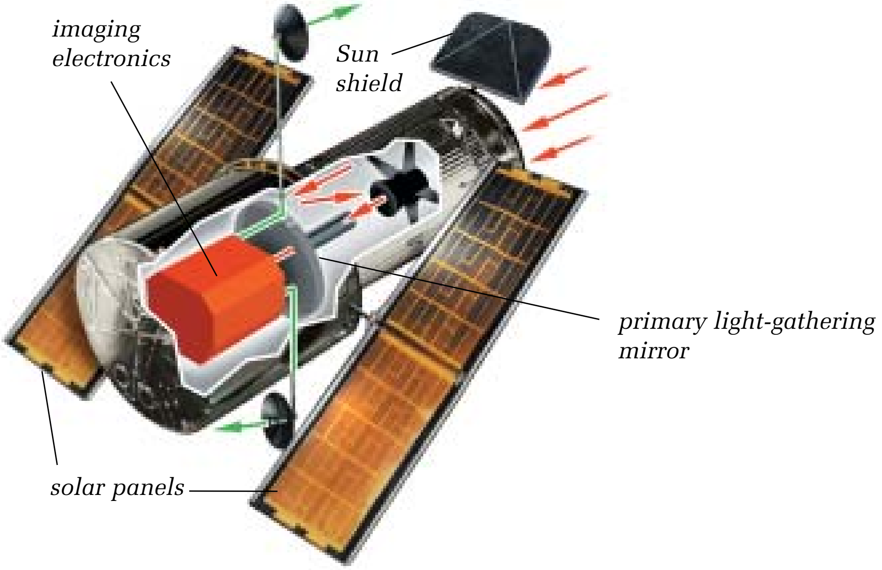

Figure 3.7 Cross-section of the Hubble Space Telescope

Figure 3.8 Earth-based telescopes are limited in their viewing ability by interference from moisture, clouds, air pollution, and light pollution.

Figure 3.9 Astronomers using the Hubble Space Telescope have discovered galaxies in parts of space where Earth-based telescopes see nothing but blackness.

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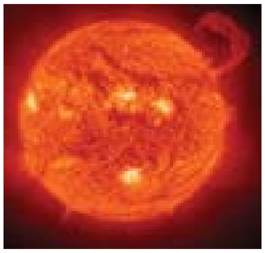
Our Eye on the Sun

The *Solar and Heliospheric Observatory* (SOHO) has been positioned about 1% of the distance from Earth to the Sun since 1996. Twelve different instruments provide details about the Sun's every action, day and night.



CHECK AND REFLECT

Key Concept Review

1. Why is there a need for telescopes?
2. What type of optical telescope uses mirrors to focus light?
3. Describe the advantage of using a segmented mirror telescope.
4. Describe the technique called interferometry.
5. The resolving power of a telescope is a measure of its:
   - a) operating ability under poor weather conditions
   - b) magnification
   - c) ability to distinguish details in an object
   - d) quality in general

Connect Your Understanding

6. Large ground-based telescopes are built with the ability to move to oppose the movement of Earth. Why is this necessary?
7. Describe two advantages of reflecting telescopes over refracting telescopes.
8. Why is the Hubble Space Telescope a reflector and not a refractor?
9. Even though it has a smaller mirror than many Earth-based telescopes, the Hubble Space Telescope can see objects more than 50 times fainter than what Earth telescopes can see. Explain why that is.

Extend Your Understanding

10. a) What happens to the detection capabilities of two reflecting telescopes working together?
    b) Would two refracting telescopes have the same capabilities? Explain your answer.
11. Imagine you had to construct an observatory on Earth for a ground-based reflecting telescope. Describe where the ideal location would be and why.

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Bee Vision

Bees and several other insects can see in the ultraviolet spectrum. Why do you think this would be an advantage for these insects?

3.2 Using Technology to See Beyond the Visible

Not all information from stars can be seen. Optical telescopes give us information based on visible light. However, objects in space, such as stars and galaxies, also emit radio waves, infrared (heat) waves, and X-rays. These are all forms of **electromagnetic energy**. This energy travels at the speed of light, 300 000 km/s, but has different wavelengths and frequencies from those of light. *Wavelength* is a measurement of the distance from one point on a wave (such as the crest) to the same point on the next wave. *Frequency* is the number of waves that pass a single point in one second.

Energy with a high frequency has a short wavelength. Gamma rays, for instance, have a high frequency (10^{20} waves per second) and a very short wavelength (less than a millionth of a centimetre). Radio waves have a low frequency, but wavelengths that can be several kilometres long.

The visible light we see all around us occupies a small section of the entire **electromagnetic spectrum**, which covers the whole range of electromagnetic energy (see Figure 3.10). Visible light has a wavelength measured in micrometeres (written as µm). One micrometre is 1 millionth of a metre.

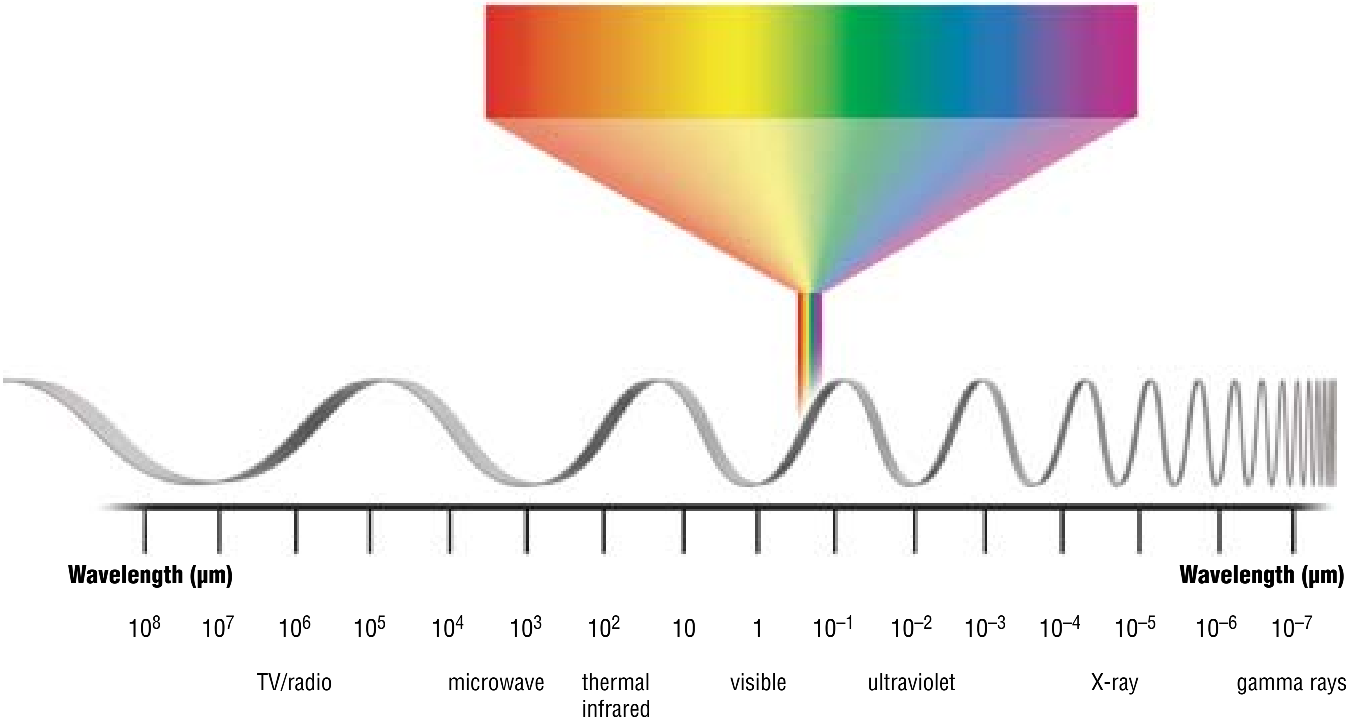

Figure 3.10 Objects in space emit a great variety of electromagnetic energy. Humans can only see the information provided in the visible spectrum, but technology enables us to detect all kinds of electromagnetic radiation.

QUICKLAB

COMPARING LIGHT SPECTRA

Purpose

To observe a variety of light sources and compare their spectra

Procedure

1. Your teacher will set up a number of spectroscopes and light sources in the lab or classroom.
2. In small groups, take turns observing the spectrum of each light source. Record any changes you notice between one spectrum and another in the variety of light sources you view.

Questions

3. What did you notice about the spectra for the different light sources?
4. Which light source produced the most distinct spectrum of all the sources? Why do you think that was the case?
5. Why won't your spectroscope allow you to see ultraviolet light or infrared?

Materials & Equipment

- spectroscopes
- a variety of light sources (fluorescent, incandescent, Bunsen burner, natural light, and other light sources)
- pencil and notebook

RADIO TELESCOPES

Studying radio waves emitted by objects in space gives astronomers data that are not available from the visible spectrum. Radio waves are received from stars, galaxies, nebulae, the Sun, and even some planets—both in our own solar system and in others. These signals are mapped through the use of sophisticated electronics and computers.

With the development of **radio telescopes**, astronomers gained several advantages over optical telescopes. Radio waves are not affected by weather and can be detected during the day and at night. They are also not distorted by clouds, pollution, or the atmosphere as are light waves. Furthermore, by focussing their radio telescopes on areas of space that appear empty, astronomers have discovered much about the composition and distribution of matter in space—information that cannot be detected by optical equipment. For example, although neutral hydrogen (a large component of matter in space) emits no light, it does emit energy at a specific wavelength in the electromagnetic spectrum. Using radio telescopes, astronomers have been able to map the distribution of neutral hydrogen in the Milky Way galaxy. This is how they learned that the shape of our galaxy is a spiral.

Figure 3.11 Because the wavelengths of radio waves are so large, the antenna of a radio telescope must be large. This radio telescope in Arecibo, Puerto Rico, has a diameter of more than 300 m. That's almost the length of three football fields laid end to end.

Radio telescopes are typically made of metal mesh. Their shape resembles that of a satellite dish: they are curved inward, with a receiver at the middle. The curved portion of the dish is really a large antenna that intercepts and focusses radio waves before transmitting them to the receiver. There, the waves are transformed into an electrical signal that is fed into a computer for interpretation.

RADIO INTERFEROMETRY

Just as several reflecting telescopes can be combined for optical interferometry, so several small radio telescopes can be combined to achieve greater resolving power than one large radio telescope can achieve (see Figure 3.12). This technique, referred to as **interferometry**, improves the performance and accuracy of radio images. The results are radio maps with valuable detail.

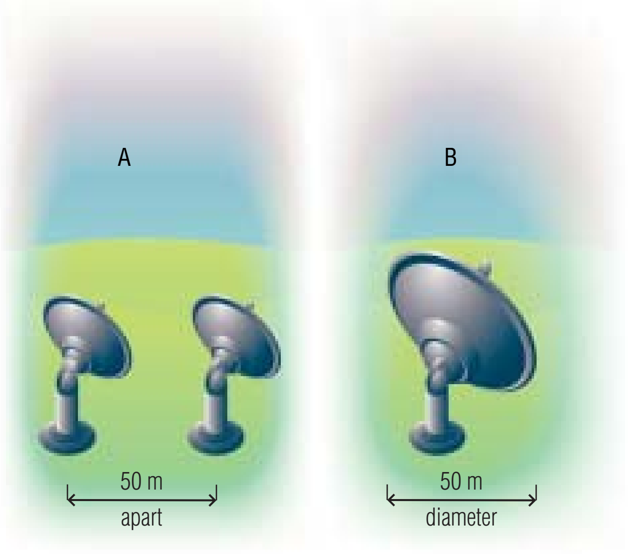

Figure 3.12 Combining information from two small radio telescopes located 50 m apart (A) simulates the resolving power of one telescope with a 50-m diameter (B). The bigger the separation between the telescopes, the more detail astronomers can measure.

The greater the distance between the radio telescopes arranged for this purpose, the more accurately they can measure position. The accuracy of measurement is increased even further if more telescopes are arranged into groups called *arrays*. The Very Large Array in Socorro, New Mexico, uses twenty-seven 25-m radio telescopes arranged in a Y pattern. The arms of the Y cover a distance of 61 km. The resolving capability of this array would be similar to that of a telescope with a diameter of 27 km!

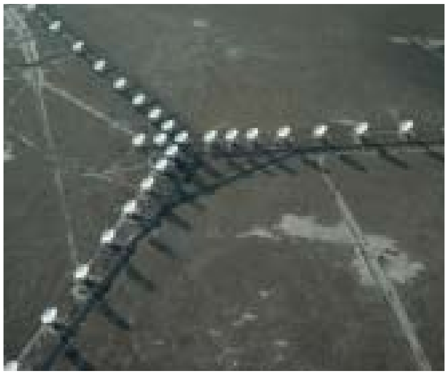

Figure 3.13 The Very Large Array simulates an antenna with a diameter of hundreds of metres.

VIEWING MORE THAN WHAT THE EYE CAN SEE

The electromagnetic spectrum offers many more opportunities to understand the workings of space than can be obtained from looking only at the visible spectrum.

For example, much ultraviolet radiation is absorbed by the atmosphere and therefore cannot be studied very well from Earth. When observed through an optical telescope, a planet orbiting a distant star is practically invisible because of the light given off by the star. However, when viewed in the infrared spectrum through a radio telescope, the brightness of the star is reduced and the planet's brightness peaks. The Keck Observatory in Hawaii is equipped to make these observations and is actively searching for planets in other solar systems.

Astronomers have discovered a variety of radiations coming from various sources in space. These include fluctuations in microwave energy that is left over from the formation of the universe; X-rays that are being emitted from objects such as black holes and pulsating stars; and huge bursts of gamma rays that appear without warning and then fade.

Nations around the world have launched numerous satellites to study each of these phenomena.

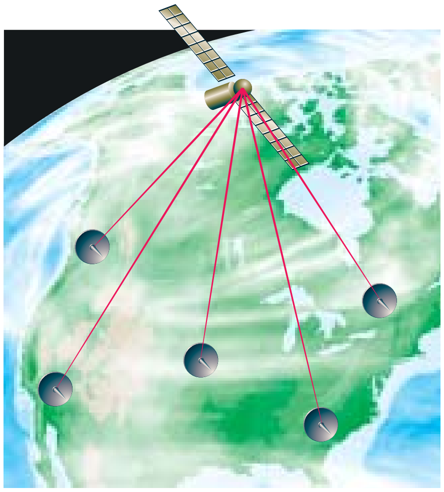

Figure 3.14 By connecting ground-based arrays with satellites in space, astronomers can simulate antennas with diameters tens of thousands of kilometres wide.

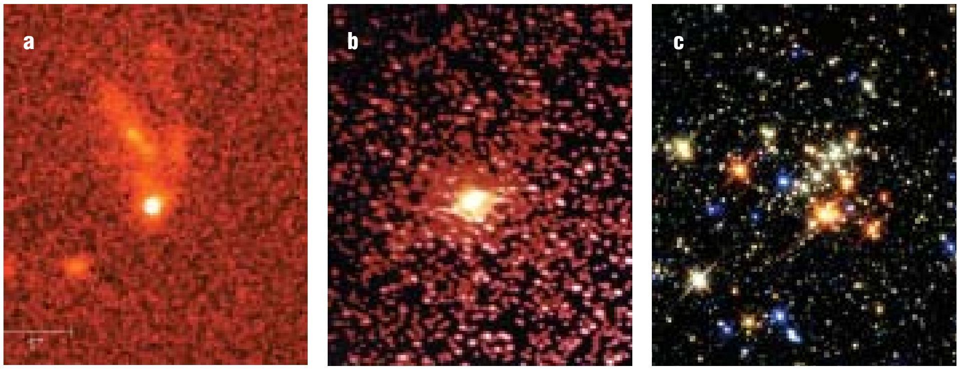

Figure 3.15 Radiation sources in space: **(a)** a gamma-ray burst, **(b)** X-rays from a black hole, and **(c)** infrared image of a young star cluster

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Gamma Ray Energy

Bursts of gamma rays occur unpredictably in different parts of space. Although they may last only a few seconds or minutes, they give off more energy than our Sun would produce in its entire 10-billion-year lifetime.

SPACE PROBES

Telescopes, optical or radio, cannot provide answers to all the questions we have about our solar system. Often it is necessary to send the observation equipment right to the object so that tests not possible to conduct by telescope can be done. In the past several decades, astronomers have done just that, sending numerous **space probes** to explore distant areas of our planetary neighbourhood. Space probes are unmanned satellites or remote-controlled “landers” that put equipment on or close to planets where it would be too difficult or dangerous to send humans to.

Space probes have been used to carry out remote sensing on Mercury and Jupiter, sample soil on Mars, land on Venus, and study the nature of Saturn’s rings. For example, the *Galileo* probe, launched in 1995, was designed to gather information about the composition of Jupiter’s atmosphere. The *Mars Pathfinder*, launched in 2000, took soil samples and performed geological tests on the planet’s rocks. It then sent the data back to Earth for analysis. The data gathered by space probes is used to find out more about how planets form in our solar system, and how the characteristics of other planets compare with Earth’s.

The table below lists some of the space probes sent in the last three decades and their missions.

Name of Space Probe	Date of Encounter	Mission
Mariner	1973–1975	Flyby of Mercury
Pioneer 11	1974–1979	Flyby of Jupiter and Saturn
Viking	1976	Mars landing
Voyagers I and *2*	1977 (launched)	Flyby of Jupiter, Saturn, Uranus, and Neptune
Venera	1982	Venus landing
Magellan	1994	Flyby of Venus
Galileo	1995	Flyby of Jupiter
Ulysses	1999	High latitude pass of Jupiter
Mars Global Explorer	2000	Orbiting of Mars
Mars Pathfinder	2000	Mars landing
Cassini	2004	Flyby of Saturn

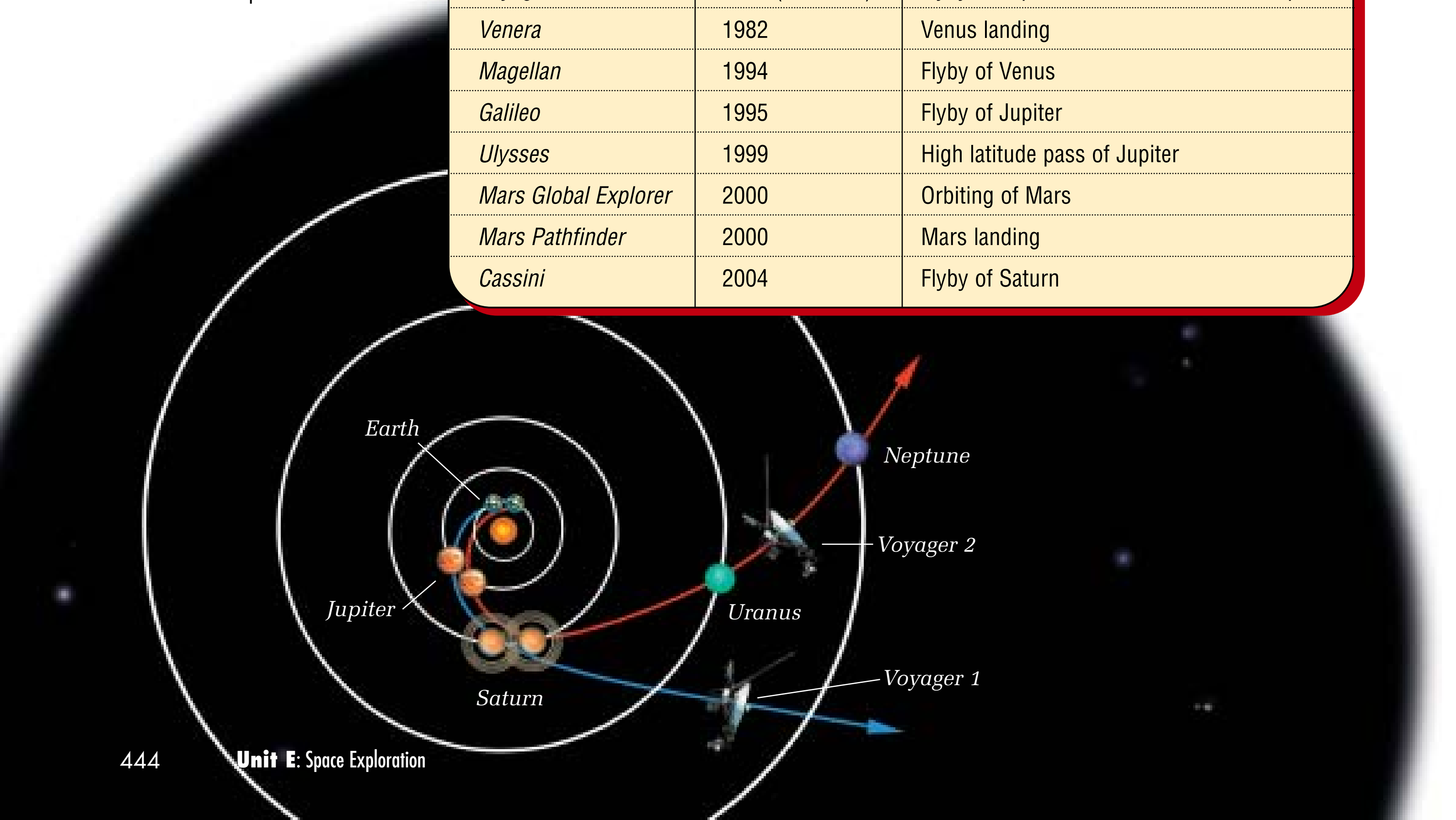


Figure 3.16 The flight paths of *Voyager 1* and *Voyager 2*. Both probes, launched from Earth in 1977, flew past Jupiter and then Saturn. At that point, *Voyager 1* was sent out of the solar system. *Voyager 2* flew on to investigate Uranus and Neptune.

Besides Earth, the only other body in the solar system that has been physically explored by humans is the Moon. That was first accomplished during the *Apollo 11* mission in 1969. Since that time, astronauts have walked across the Moon, driven a dune buggy on it, and taken a golf swing there. The lunar rocks they collected have been brought back to Earth.

The next great adventure in interplanetary exploration will be a manned flight to Mars and back. The entire journey could last up to three years and would be extremely dangerous. That is why it is essential to find out as much as possible by sending space probes and robot explorers to the planet first.

reSEARCH

Satellite Specialties

You have been introduced to a variety of forms of electromagnetic radiation in this section. Research the names of some satellites that have been designed to observe and study a) infrared radiation; b) X-rays; and c) gamma rays. Find out about Canada's involvement in the development of these satellites. Begin your research at www.pearsoned.ca/scienceinaction.

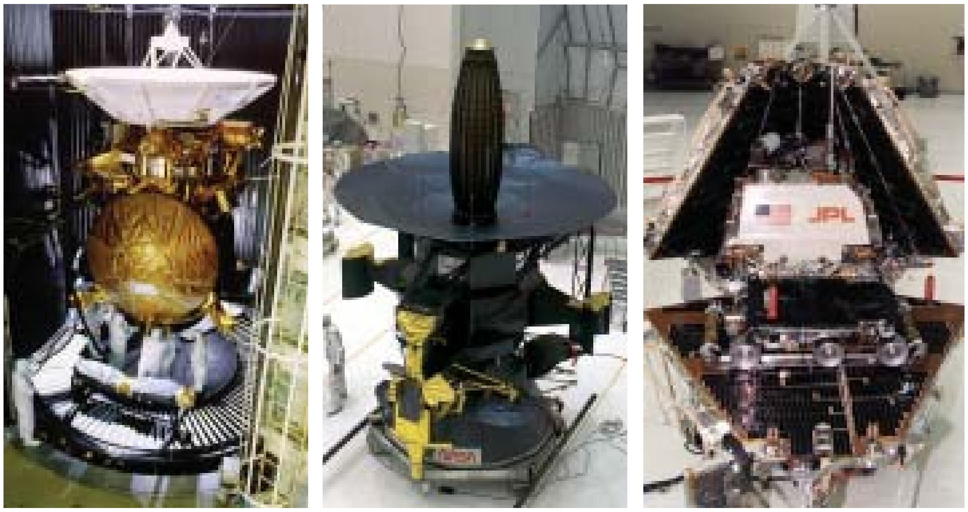


Figure 3.17 These photographs show the preparation of three different space probes. Each probe must be completely free of contamination, which is why all the workers visible in the photos are wearing specially designed hygienic suits.

CHECK AND REFLECT

Key Concept Review

1. What is electromagnetic radiation?
2. Name four other forms of electromagnetic radiation besides visible light.
3. How is wave frequency related to wavelength? Support your answer with a sketch.
4. What advantages are there to using space probes rather than manned flights?

Connect Your Understanding

5. What are the sources of radio waves from space?
6. Why aren't television signals visible to us?
7. Explain two advantages of using radio telescopes instead of optical telescopes.

Extend Your Understanding

8. a) Explain how all forms of electromagnetic radiation are similar to each other.
   b) Explain how each form is different from the others.
9. When combining information from multiple telescopes, the length of the distance between the telescopes is very important. Is there a limit to how far that distance can be: a) on Earth? b) in space?

3.3 Using Technology to Interpret Space

Telescopes tell us a great deal about the universe, but as you learned in section 3.2, there is much more information in addition to what we can see. Just by looking, we can't tell how far away a star is, what its composition is, or whether it is moving toward or away from us. To discover and understand these and other characteristics, we need to tackle the problem by technological means, whether by using a simple tool or machine or operating a highly complex system of instrumentation.

GIVE IT A TRY

LIGHT BULB STARS

Without the use of technology, we are limited in the amount of information we can get about stars. Still, that doesn't mean we can't get *any* information. Your teacher will put two small lamps, each with a different sized light bulb, on a desk or table at the front of the classroom. Your desk will be Earth and the light bulbs will represent stars far away. List all the things you can tell about the stars just by looking at them from Earth.

MEASURING DISTANCE

Triangulation and parallax are two ways of measuring distances indirectly, on the ground or in space.

Triangulation

Triangulation is based on the geometry of a triangle. By measuring the angles between a baseline and the target object (such as a tall tree or a water tower), you can determine the distance to that object.

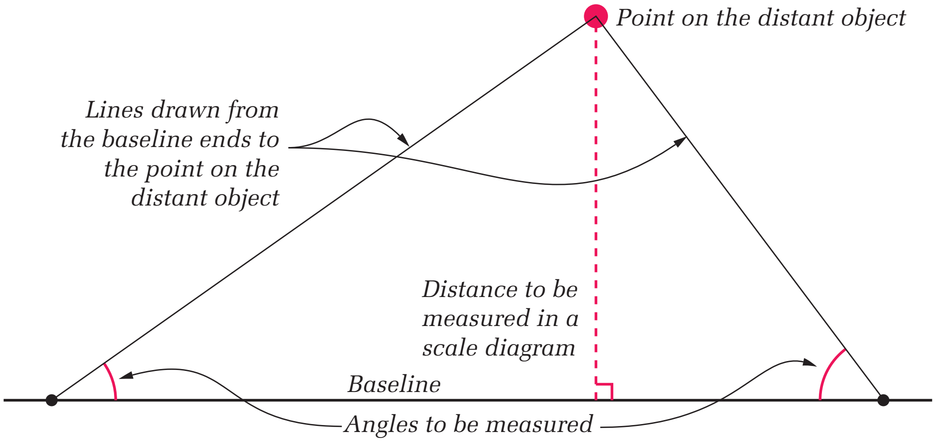
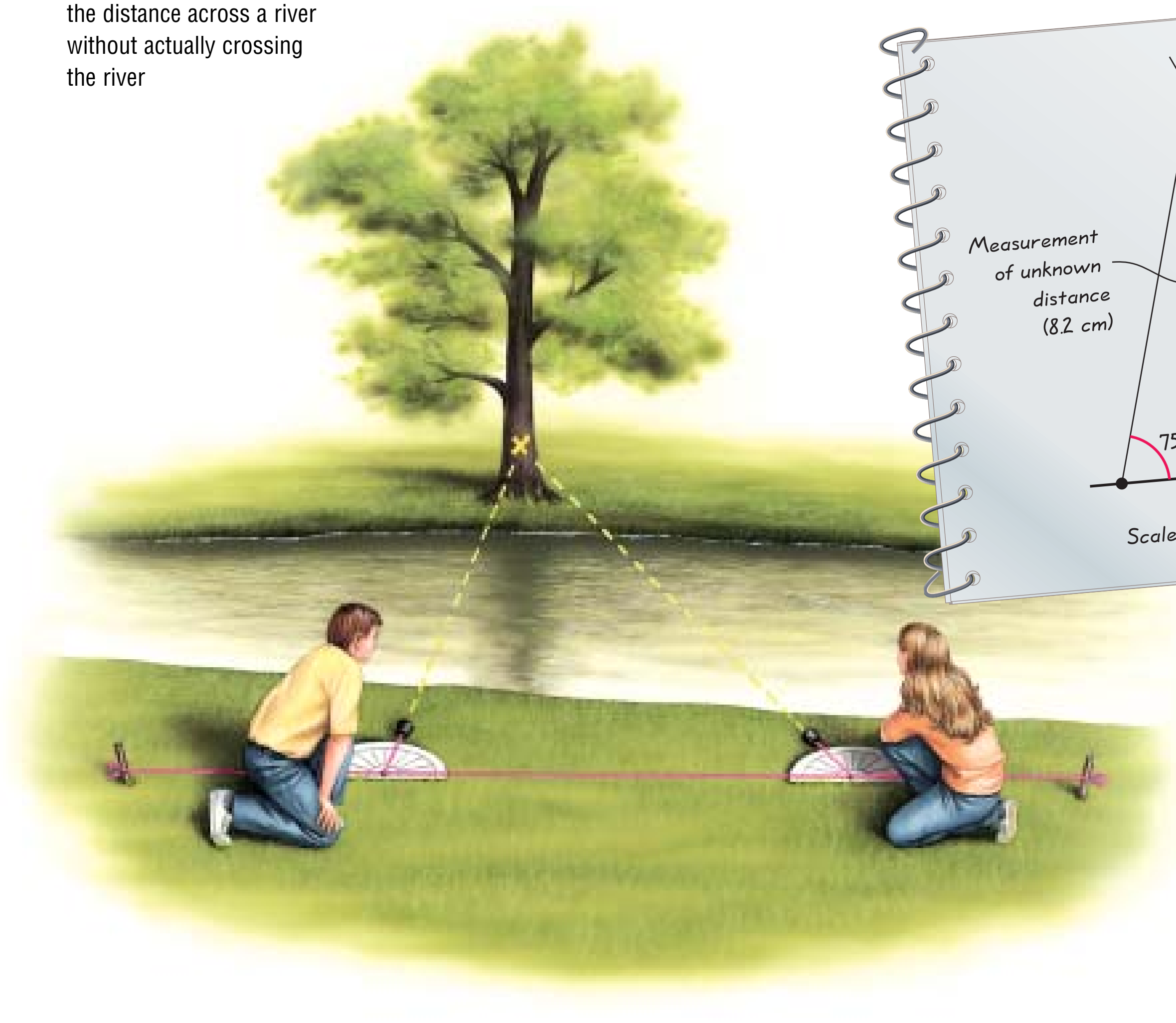


Figure 3.18 To measure a distance indirectly using triangulation, you must know the length of one side of the triangle (the baseline) and the size of the angles created when imaginary lines are drawn from the ends of the baseline to the same points on the distant object.

For instance, you could use triangulation to measure the distance across a river without actually crossing the river. The procedure is as follows:

1. On a flat area along the bank of the river, measure off an accurate baseline and mark each end of the line so that you can identify it easily.
2. Select an object to be your viewing target on the opposite bank.
3. Standing at one end of the baseline, use a protractor to determine the angle between your sight line to the object and the spot on the baseline where you are standing.
4. Stand at the other end of the baseline and again determine the angle from that spot to the object.
5. Make a scale drawing of a triangle using the length of the baseline and the two angles.
6. On your drawing, mark a perpendicular line from the baseline to the object. Measure this line and use the scale to convert it to actual length. This will give you the distance across the river.

Figure 3.19 Using triangulation to measure the distance across a river without actually crossing the river



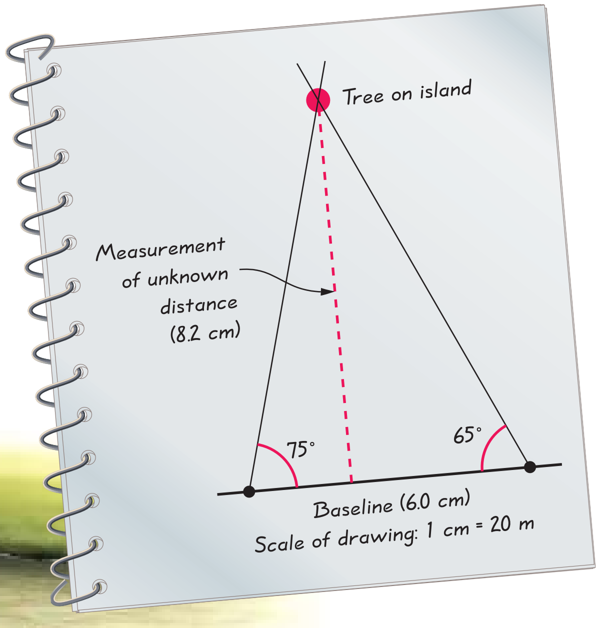


Figure 3.20 A scale drawing of the triangulation procedure

Activity E-6

Inquiry

HOW FAR IS IT?

The Question

How accurately can the length of a playing field be measured using triangulation?

The Prediction

You will be calculating percent error for this activity. Predict the degree of accuracy that you expect. Example: *Our calculations will be off by 10%.*

Materials & Equipment

- measuring tape (at least 50 m long)
- two metre-sticks
- protractor
- paper
- pencil
- ruler

Procedure

1. Copy the table below into your notebook.

Baseline length (m)	Angle from position (A) (°)	Angle from position (B) (°)	Calculated length of field (m)	Actual length of field (m)	Percent error (%)
10					
20					
50					

2. Go outside to a large flat area, ideally a soccer or football field.
3. Working in a small group, use the measuring tape to measure off a baseline of 10 m along the goal line of the field.
4. Stand a metre-stick in the ground at each end of the baseline to serve as guideposts (A) and (B).
5. Standing at one end of the baseline (A), looking directly at the right goal post at the far end of the field. Determine the straight line betweem A and the right goal post. Measure the angle between this line and the baseline. In your data table, record the angle you found. Repeat this step from the other end of the baseline (B) and again record the angle.
6. Repeat steps 3 to 5, using a baseline of 20 m and then one of 50 m.

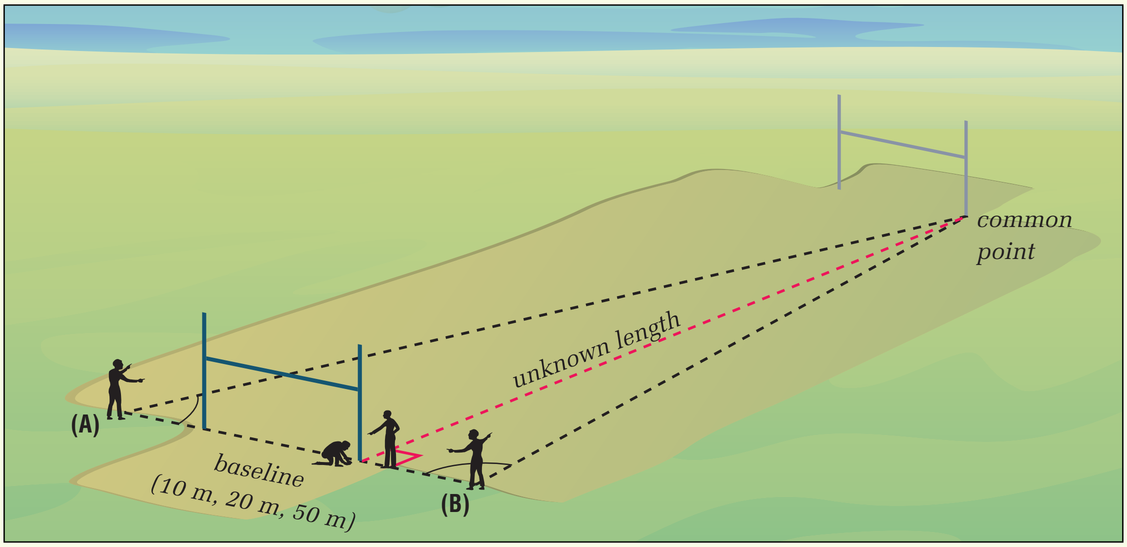


Figure 3.21 Step 5

Analyzing and Interpreting

7 For each baseline length, make a scale drawing of a triangle, using the two angles you measured each time. Use a scale of 1 cm = 5 m.

8 On each of your scale drawings, measure the length of the field and record your results in the table. Do you get the same length for all three baselines? Explain your answer.

9 Find the actual length of the field (either measure it directly, or ask the athletic director of your school). Add this information to your table.

10 Calculate the accuracy of your results for each baseline length. Use the percent error equation below. Record these figures in the table.

$$\text{percent error} = \frac{(\text{actual value} - \text{measured value})}{\text{actual value}} \times 100$$

11 Determine the average of your three lengths and calculate the percent error.

Forming Conclusions

12 How accurate was your calculated average length of the playing field?

13 Which baseline resulted in the most accurate field length? Explain why that was.

14 How close were you to your predicted error?

Applying and Connecting

For a technique like this to work, precise measurements must be made. With reference to your percent error, describe what you think may be sources of error in this activity. What are the limitations of using triangulation on the ground? How do these limitations compare with those that apply when one is using triangulation to find distances to stars?

Parallax

Parallax is the apparent shift in position of a nearby object when the object is viewed from two different places. For a quick example of parallax, hold out your arm and stick up your thumb. With your right eye closed, look at an object on the far wall behind your thumb. Now, look with your left eye closed. You will notice how the background to your thumb appears to have moved.

Astronomers use a star's parallax (that is, its apparent shift in position relative to the background stars) to determine what angles to use when they triangulate the star's distance from Earth. When triangulation calculations are made, the longer the baseline, the more accurate the results. The longest baseline we can use from Earth is the diameter of Earth's orbit. This means that measurements must be taken six months apart to achieve the maximum baseline length (see Figure 3.22).

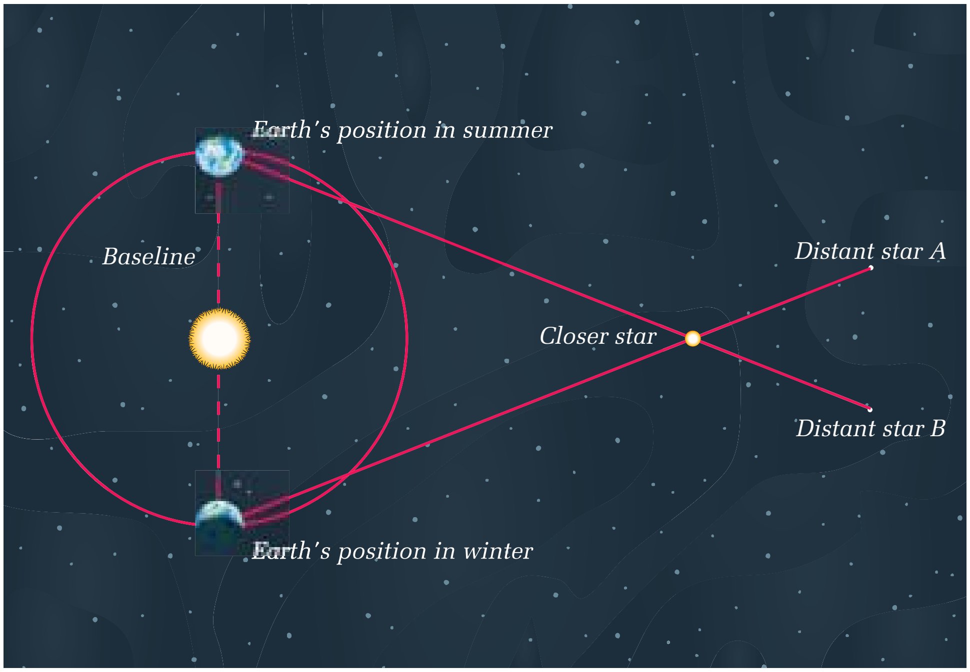


Figure 3.22 When viewed from Earth at different times of the year, a nearby star will appear to shift its position relative to different distant stars in the background. The angles between each end of Earth's baseline (the extreme ends of its orbit, six months apart) and the target star provide angles for triangulation.

ACTIVITY E-7

Inquiry

ANALYZING PARALLAX

The Question

Which show greater parallax: close objects or distant objects?

Materials & Equipment

- a tall candle (about 25 cm long)
- black board or white board
- paper and pencil

Procedure

1. Set the candle on a table 50 cm in front of the board.
2. On the board, draw 10 evenly spaced vertical lines and label them A through J.
3. From a position on the right-hand side of the classroom about 4 m back from the board, look at the candle using only one eye. Make a sketch of its apparent position relative to the reference lines drawn behind it.
4. Go to the other side of the classroom and repeat step 3. What changes in your observation did you notice from one position to the other?
5. Move 2 m closer to the candle and repeat steps 3 and 4. Make sketches of your observations each time. What changes do you notice from the sketches you made from the 4-m position?
6. Move 2 m back from your original position and repeat steps 3 and 4. What difference do you notice this time?
7. The teacher will now move the candle closer to the board. Stand at the very back of the classroom and again repeat steps 3 and 4.
8. Compile your observations in one table.

Figure 3.23 Step 1

Analyzing and Interpreting

9 Describe the apparent motion of the candle as you moved closer to or farther away from it. In which of your positions was the apparent shift of the candle the i) greatest? ii) least?

10 Draw an overall map-view sketch that illustrates the apparent shift in steps 3 and 4.

Forming Conclusions

11 Describe how distances to stars can be measured using parallax.

12 Is parallax more useful for measuring distances to near objects or distant objects? Explain your answer.

Applying and Connecting

Although the technique using parallax has been around for hundreds of years, it was not originally used for determining distances to stars. How do you think parallax could be used to measure short distances on the ground? What would be the limitations of using parallax to measure distances on Earth?

Determining a Star's Composition

As you recall from earlier studies, white light is actually a combination of all colours (the "rainbow" colours). White light can be separated into its component colours by being shone through a prism. The result is bands of colour, which together are referred to as the *visible spectrum*.

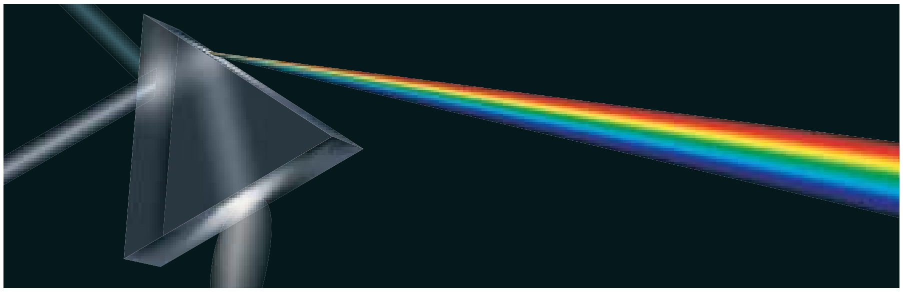


Figure 3.24 Like other light, starlight can be separated into its spectral colours. Isaac Newton was the first person to separate sunlight and analyze its spectrum.

When astronomers first began refracting the light from stars to examine it, they noticed that different stars had dark bands in distinct sequences and thicknesses on their spectra. They discovered that this happened because the various elements in a star absorb light in different ways. As a result, each element creates its own black-line "fingerprint." Astronomers compare the spectrum of a star with known spectra of elements to determine the star's composition. They use an instrument called a **spectrometer** to do this.

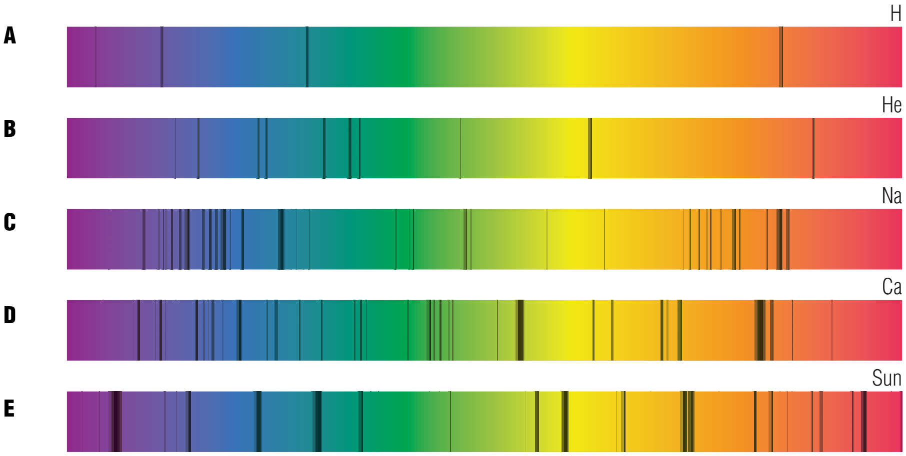


Figure 3.25 The spectra of (A) hydrogen, (B) helium, (C) sodium, and (D) calcium. The Sun's spectrum is shown in (E).

Determining a Star's Direction of Motion

Have you ever noticed how the sound of a siren on an emergency vehicle seems to change as it approaches, passes, and then moves away from you? The reason has to do with the changes in *pitch*, the frequency of sound waves. The pitch of the siren is higher as the vehicle comes toward you than it is after the vehicle goes by and moves away from you. This occurs because the sound wavelengths become compressed in front of the vehicle as the vehicle approaches, causing the pitch to rise. As the vehicle moves away, the wavelengths behind the vehicle are no longer squeezed. As they stretch out, the sound falls in pitch. This is called the **Doppler effect**.

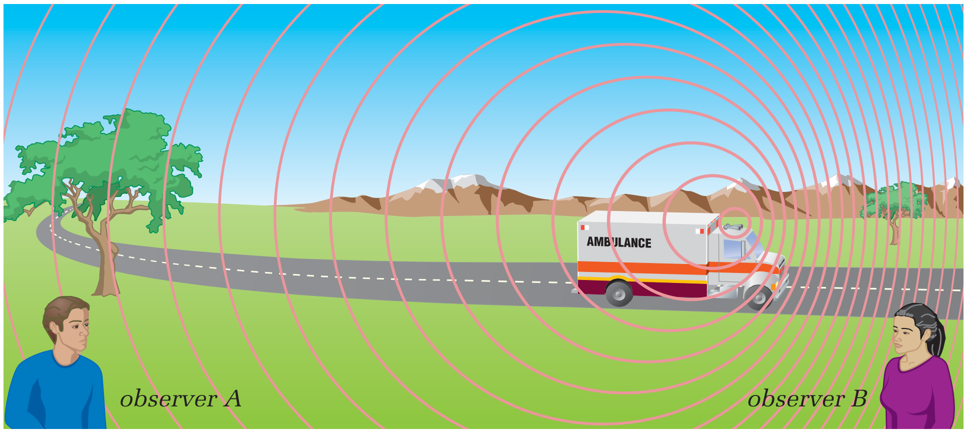


Figure 3.26 Even if you could not see an emergency vehicle, you would be able to tell by the sound of the siren whether the vehicle was moving, and approaching you or travelling away from you.

Like sound, light also travels in waves. Changes in those waves can be used to measure how fast and in what direction a light-emitting object is moving. Pitch refers to the shift in the sound waves of a moving object. The position of the dark bands in the light spectrum is what shifts in the light waves of a moving star. The spectrum of an approaching star shows the dark lines shifting to the blue end of the spectrum as the light's wavelengths become compressed. In the spectrum of a star moving away from Earth, the dark lines shift to the red end as the wavelengths stretch out. The amount of that shift shows up in observations of a star indicates the speed at which the star is approaching or receding.

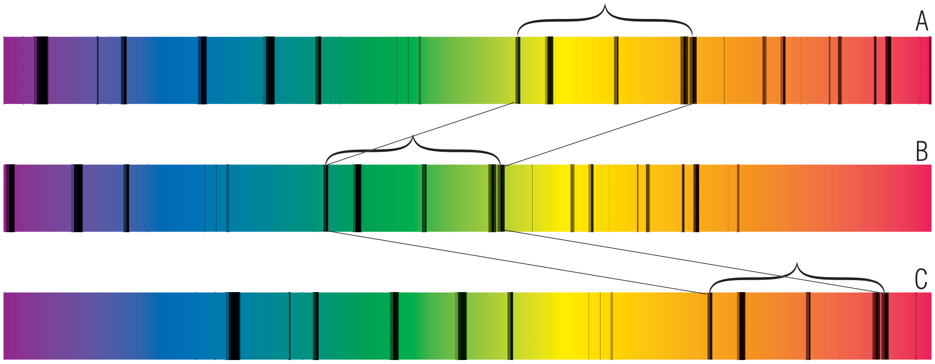


Figure 3.27 Analyzing the blue-shift and red-shift in the spectra of stars and galaxies shows astronomers whether the bodies are moving toward Earth (B) or away from Earth (C). No shift in the spectrum means that the star and Earth are moving in the same direction (A). The star is then said to be stationary.

The Doppler effect comes into play in a number of everyday applications. One of the most common is the radar gun used by police to detect drivers who are travelling above the speed limit. The radar gun emits a radio signal with a known wavelength. A moving car generates a returning wave whose wavelength is picked up by the radar gun. The size of the difference in the two wavelengths shows how fast the moving vehicle is travelling.

Figure 3.28 Radar guns used to enforce traffic speed limits were developed based on scientific understanding of the Doppler effect.

GIVE IT A TRY

EXPERIENCING THE DOPPLER EFFECT

(Teacher Demonstration)

The Doppler effect refers to the change in frequency of sound, light, and other waves, which results from the relative motion between an observer and the source of the waves. In this activity, you get the chance to experience the Doppler effect firsthand. You are the observer and the source of the sound waves is a noise-maker.

1 While you are seated at your desk, your teacher will stand in the centre of the classroom and swing a small battery-powered noise-maker overhead. Because the noise-maker will be tied to a long string, its circular path will be very wide.

2 As the noise-maker moves overhead, listen for the change in sound as the noise-maker approaches you and then moves away from you. How would you describe the differences in sound?

3 Listen again while the teacher spins the object, but this time close your eyes. Are you able to tell when the object is coming toward you and when it is moving away from you? Explain your answer.

4 In what ways is this apparent shift in sound similar to the shift that happens in a star's spectrum? Use a diagram to help you illustrate your answer.

CHECK AND REFLECT

Key Concept Review

1. Explain the meaning of triangulation and give an example of a situation in which it might be used.
2. How is parallax used to measure distances in space?
3. a) What is a spectrum?
   b) What can a star's spectrum indicate about a star?
4. What is the Doppler effect? Give an example of its use.

Connect Your Understanding

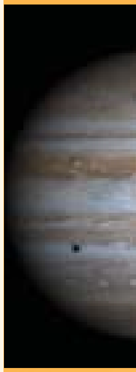
5. When using the triangulation technique, why is it important to measure the baseline accurately?
6. How do astronomers determine the elements that make up a star?
7. Explain why the spectra of some stars shift.

Extend Your Understanding

8. What type of shift in the spectrum would you expect from a star that was:
   a) moving in the same direction as Earth, at the same speed as Earth?
   b) moving at right angles to the direction of sight?
9. What conditions would have to be met in order for an ambulance with its siren on not to exhibit the Doppler effect when it passes you?

Figure 3.29 These ripples show energy being transmitted from one place to another. How is this similar to the way in which visible light and other forms of electromagnetic radiation travel?

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. With the aid of two diagrams, describe how refracting and reflecting telescopes work.

2. Explain why infrared telescopes would not be useful for stargazing in a city.

3. What is the advantage of using telescopes set up in an array?

4. What is a spectrometer used for?

5. If you see a red-shifted star, what does that tell you about the direction in which the star is moving through space? Explain your answer.

Connect Your Understanding

6. You are the owner of a company that wants to build the largest optical telescope in the world. Which type would you choose and why?

7. Why can radio astronomers make observations at any time during the day, but optical astronomers are mostly limited to making their observations at night?

8. Why do different elements in a star display different patterns of lines in their spectra?

9. Why is the Doppler effect important to astronomers?

Extend Your Understanding

10. *Most professional astronomers spend little time looking through a telescope lens.* Explain why you agree or disagree with this statement.

11. Describe one limitation in using parallax to determine a star's distance from Earth.

Focus On SCIENCE AND TECHNOLOGY

The advance of space technology has been the result of hundreds of years of research and development. Ideas have developed over generations and have been improved on. This has helped answer many questions humans have had about the universe, while at the same time opening up even more mysteries. Consider the following questions:

1. What has motivated humans to advance the technology used to study the stars?

2. Why is it essential for ideas and technologies to be shared in order for humans to improve their understanding of space?

3. How could the advancement of space observation technology benefit society?

4.0

Society and the environment are affected by space exploration and the development of space technologies.

Key Concepts

In this section, you will learn about the following key concepts:

- space exploration risks and dangers
- technologies for space exploration and observation
- life support technologies
- ownership and use of resources in space

Learning Outcomes

When you have completed this section, you will be able to:

- recognize the risks and dangers associated with space exploration
- describe Canadian contributions to space research and development and to the astronaut program
- identify and analyze factors that are important to decisions regarding space exploration and development

From cancer treatments and pacemakers, to Teflon and flat-screen televisions, the technological benefits created by space research are now everywhere in our daily lives. All of these innovations—many developed for use in the International Space Station—got their start fulfilling a purpose in space exploration. Opportunities for the economic development of space resources are also being investigated today, including such ideas as offering tourist space flights, building hotels on the Moon, and mining minerals on asteroids.

At the same time, the study of space has made us aware of the many hazards that lie beyond Earth's protective atmosphere. For example, we are learning more about the destructive effects of solar radiation on life and equipment and about the danger of possible collision with comets and asteroids. As well, many environmental and ethical issues have arisen related to space exploration. Who owns space? Who is entitled to use its resources? Who is responsible for cleaning up the space environment? How can we justify spending billions of dollars to send a few people into space when millions of people on Earth do not have clean drinking water? These and other matters are discussed in this final section of the unit. You will also read about Canada's significant contributions to space research and the astronaut program.

4.1 The Risks and Dangers of Space Exploration

Space exploration is an exciting endeavour. Yet, as for any journey into the unknown, there are dangers. Travel into space is an especially high-risk business. As you learned in Section 2.0, the space environment is not "human friendly." Only by understanding the dangers and developing technologies to overcome those obstacles have humans accomplished what they have. Unforeseen dangers still remain. Accidents related to space travel may result not only in loss of human life, but in immense economic loss and the loss of countless years of work.

In 1967, the three-member crew aboard Apollo 1 died during a training exercise when fire broke out on board the spacecraft. In 1986, the space shuttle *Challenger* experienced a catastrophic explosion shortly after take-off, killing all seven astronauts aboard. Both the Russians and Americans lost Mars probes shortly before the crafts arrived at the planet. In both of those cases, hundreds of millions of dollars and thousands of hours of labour were lost.

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What Goes Up ...

By mid-2001, about 2700 satellites were known to be orbiting Earth. Only about one-third of those are actually working. The rest are "space junk," and most will eventually burn up during re-entry into Earth's atmosphere.

Figure 4.1 As the explosion of the space shuttle *Challenger* showed in 1986, space exploration is an extremely high-risk undertaking.

Nothing can be taken for granted during the preparation for a manned or unmanned space flight. Something as seemingly straightforward as calculating the amount of fuel needed for the flight requires the utmost attention to detail. During *Apollo 11's* mission to the Moon in 1969, the original landing site for the *Eagle* was found to be too rocky for the lunar module to set down safely. Faced with having to choose another place to land, the astronauts knew they had to find the right spot with one try. They didn't have enough fuel to change their minds and find another site—not if they wanted to get back to Earth after their visit to the Moon.

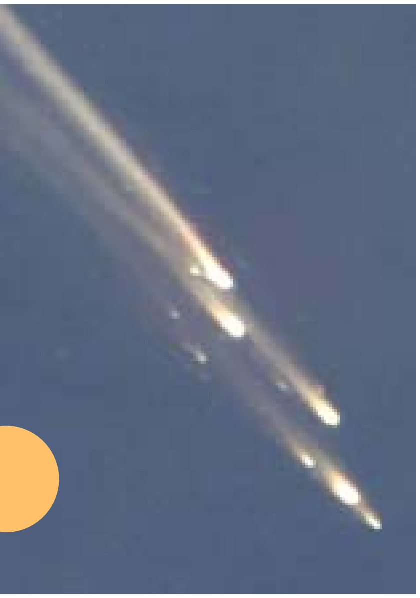

Figure 4.2 In early 2001, the abandoned Russian space station *Mir* came hurtling through Earth's atmosphere, burning up on re-entry.

THE DANGERS OF MANNED SPACE TRAVEL

Sending humans into space has always been a dangerous proposition. First, just imagine the risks associated with being strapped into a small cockpit above several hundred tonnes of highly explosive fuel. Poor weather conditions, malfunctioning equipment, and even the presence of birds can interfere with launching a rocket.

Once a manned craft is in space, floating debris, meteoroids, and harmful doses of radiation must be faced. Outside of Earth's protective atmosphere, the effects of solar and cosmic radiation are magnified because there is no protection. For example, the huge blast of electrically charged particles that the Sun sometimes emits (in a "coronal mass ejection") can burn up the electronic circuits in a satellite. In humans, this dose of radiation also kills cells in vital organs and damages bone marrow. The occurrence of coronal mass ejections (solar flares) is monitored by NASA, and astronauts are warned so that they can protect themselves inside polyethylene shielding that absorbs the radiation.

Cosmic radiation comes from the Milky Way and other galaxies. The damage to human cells from this form of radiation is extreme.

Returning to Earth has its dangers too. The path that the spacecraft follows on re-entry into Earth's atmosphere must be perfect. If it is too shallow an angle, the craft can bounce off the atmosphere and back into space (like a stone skipping across the surface of a pond). If it is at too steep an angle, the craft can move too quickly through the atmosphere and burn up.

*info***BIT**

Stick to the Menu

Not finding the dehydrated "space food" very tasty, one of the early astronauts smuggled two corned beef sandwiches onto a space flight. Mission Control found out and was furious. The mass of the craft and its payload had been calculated to the nearest gram, and the fuel required for the flight had been calculated to the nearest millilitre.

SPACE JUNK

Another legacy of the human presence in space is "space junk." **Space junk** refers to all the pieces of debris that have fallen off rockets, satellites, space shuttles and space stations, and remain floating in space. The debris includes bits as small as flecks of paint or a bolt, and large items such as dead satellites. Lost antennas, tools from past shuttle flights, and even a camera released by an astronaut are other examples. If the space garbage is just above the outer reaches of Earth's atmosphere, it can stay in orbit for thousands of years.

The Hazards in Space

Since 1957, more than 4000 missions have been sent into space. Each one has left its own bits of debris. The space shuttle and International Space Station are constantly being bombarded by tiny pieces of space debris called micrometeorites. These are very hard to detect in space, and travel with lethal velocities. A micrometeorite piercing the hull of a space craft would cause catastrophic damage.

A small washer or screw sounds insignificant compared to a satellite, space shuttle, or space station. However, if you consider that those items are moving 20 000 km/h, you can understand that the effects of a spacecraft colliding with even the smallest object would be devastating. That small object would have a higher impact velocity than a fired bullet.

Most space junk will burn up if it passes through Earth's atmosphere, but until it does, it will remain a very real threat to anyone or anything travelling into space.

The Hazards on Earth

Some space junk poses a risk to Earth as well. There is always the possibility that pieces of obsolete satellites can make their way back to Earth's surface. One such example occurred in January 1978, when a nuclear-powered Soviet satellite crashed into the Great Slave Lake area of the Northwest Territories. On re-entry to Earth's atmosphere, the satellite disintegrated, showering radioactive debris over 124 000 km^2. No lives were lost, but clean-up by Canadian and U.S. military personnel took almost eight months and cost $15 million (Cd.).

reSEARCH

Fuelling a Spacecraft

Just getting into space requires tremendous amounts of fuel. Find out how much each solid fuel rocket tank on the American space shuttle holds. Begin your search at www.pearsoned.ca/scienceinaction.

Figure 4.3 An impact crater (greatly magnified) on a window on the space shuttle *Challenger* following its 1983 mission. The pit contains traces of titanium oxide—which might have originated from a flake of paint.

CHECK AND REFLECT

Key Concept Review

1. Name four dangers faced by astronauts during space missions.
2. What happens to satellites that run out of power or just reach the limit of their usefulness?
3. What is meant by "space junk"? Provide examples in your answer.
4. Why must a spacecraft's angle of re-entry into Earth's atmosphere be carefully calculated?

Connect Your Understanding

5. For what reasons would NASA be concerned about something as small as a lens cap floating in space?
6. Why do astronauts on the space shuttles and working in the International Space Station receive more exposure to solar radiation than people on Earth do?
7. Explain why NASA monitors coronal mass ejections.

Extend Your Understanding

8. a) What causes the vast majority of space debris to burn up as it passes through Earth's atmosphere?
   b) Why does some space debris, such as a meteorite, not burn up totally as it passes through Earth's atmosphere?

4.2 Canadian Contributions to Space Exploration and Observation

Canada has had a proud involvement in the development of technology for space exploration and observation. One of its most famous contributions is the robotic arm, the "Canadarm," originally designed by Spar Aerospace. Since its debut in 1981 on the U.S. space shuttle *Columbia*, the Canadarm has proven to be one of the most versatile pieces of technology ever designed for the space shuttle program. Manipulated by remote control, the Canadarm has launched and retrieved satellites, helped fix optical apparatus on the Hubble Space Telescope, and put together modules of the International Space Station.

infoBIT

Robert Thirsk

In 1996, Canadian astronaut Robert Thirsk spent 17 days on board a space shuttle. Thirsk, who set his sights on space flight at a young age, holds four university degrees, including a Bachelor of Science from the University of Calgary.

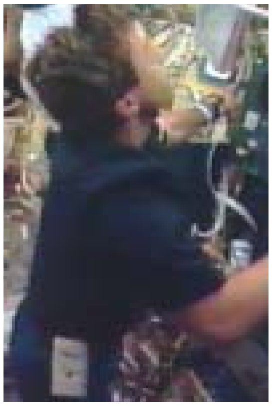

Figure 4.4 Canadarm 1 in action

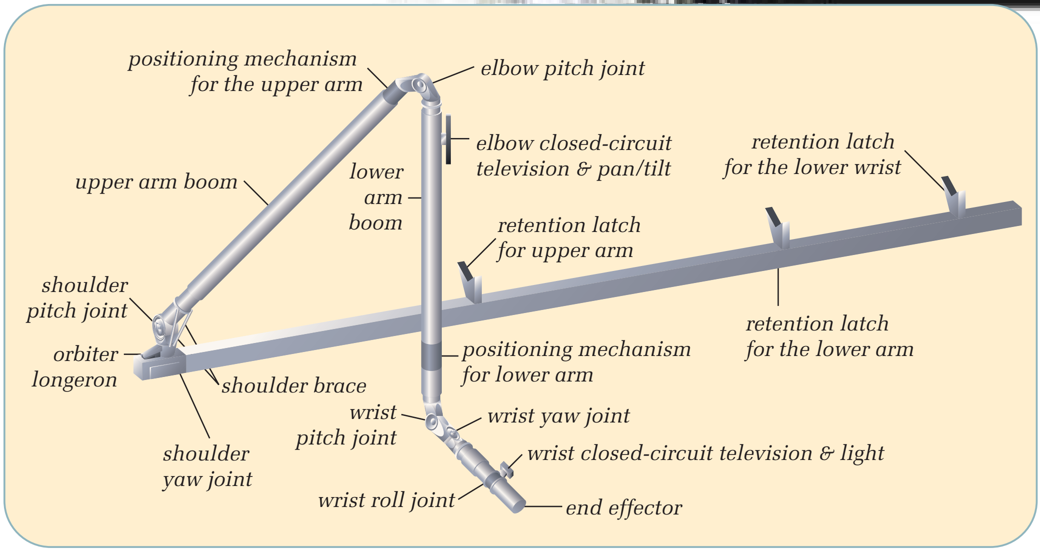

Figure 4.5 The parts of the Canadarm 1

When it launched *Alouette 1* in 1962 (pictured in Figure 2.5), Canada became among the first nations in the world to use a satellite for non-military purposes. A decade later, in 1972, Canada launched *Anik 1* from Cape Canaveral in Florida. That satellite gave the whole country telecommunications coverage for the first time. A year after that, Canada became the first country in the world to use satellites to broadcast television. Since then, the nation has continued to be a leader in the development and use of satellites for communication purposes.

The next generation of Canadian space robotics is the Canadarm 2. Not only can the arm bend around corners and grasp objects with its computer-controlled fingers, it can also move itself around the outside of the International Space Station, crawling like a caterpillar and making every part of the space station accessible.

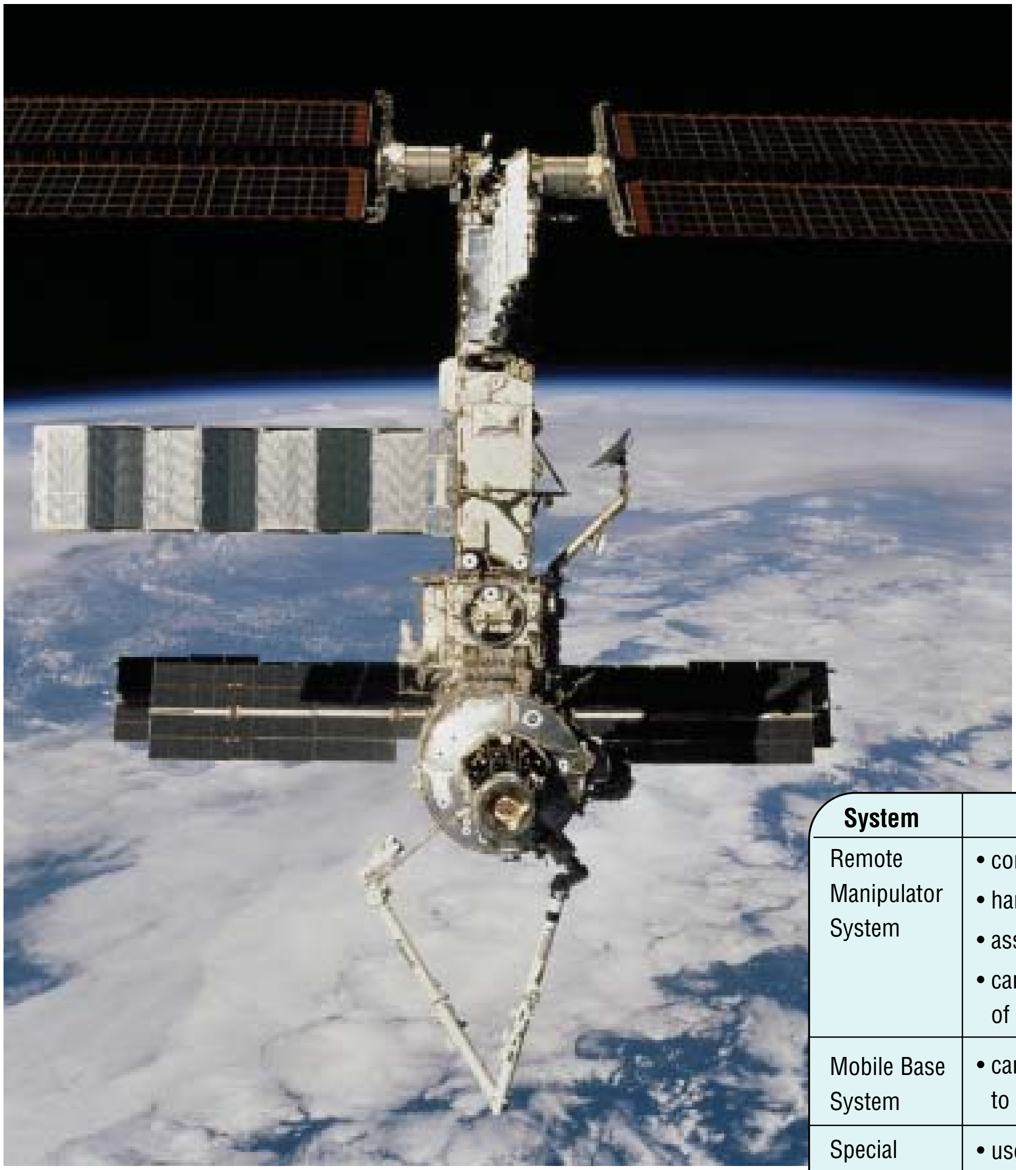

Figure 4.6 Canadarm 2, shown here in position on the International Space Station, is bigger, stronger, and smarter than its predecessor, Canadarm 1.

System	Description
Remote Manipulator System	• contains seven motorized joints • handles large payloads • assists with docking the space shuttle • can move itself around different parts of the station
Mobile Base System	• can travel along a rail system to move to different positions on the station
Special Purpose Dexterous Manipulator	• uses its two-armed robotic hand for delicate assembly work

Figure 4.7 Three main systems of the Canadarm 2

GIVE IT A TRY

WHAT DOES IT TAKE TO BECOME AN ASTRONAUT?

Millions of dollars are spent to train people for the astronaut program and to send a few of them into space. Added to that large financial cost are the thousands of hours of work put in by hundreds of support personnel (researchers, technicians, engineers, physiologists, and others). Obviously, choosing suitable candidates for the astronaut program is critical in making this investment of time and money worthwhile. Candidates cannot just be randomly selected from a list of all applicants. What special education, skills, and other qualifications does someone need to become an astronaut?

1 In a small group, brainstorm a list of criteria that you think a candidate should have to be the "ideal astronaut."

2 Research the Canadian Space Agency's requirements for a person to become an astronaut.

3 Research the biographies of three Canadian astronauts of your choosing. Make note of any patterns or similarities you notice in their backgrounds.

4 Compare your initial brainstorming list with the actual requirements from the Canadian Space Agency. How did your list compare with your research on the backgrounds of actual Canadian astronauts?

5 Present your findings to the class.

6 As a class, discuss whether or not there is such a thing as an "ideal" candidate to be an astronaut.

7 With reference to your research, explain why you would or wouldn't make a good candidate to be an astronaut.

Materials & Equipment

- computer with Internet access
- library (school or public)
- pencil and paper

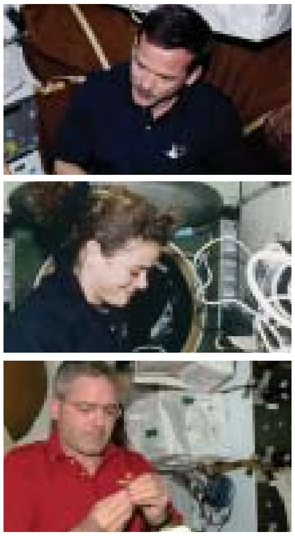

Figure 4.8 From top to bottom, Canadian astronauts Chris Hadfield, Julie Payette, and Marc Garneau

Figure 4.9 Headquarters of the Canadian Space Agency

Canada's rich history in the field of space technology includes the following highlights:

- In 1839, Sir Edward Sabine established the first magnetic observatory at the University of Toronto. He discovered that the aurora borealis was associated with sunspot activity.
- In 1962, Canada became the third nation on Earth to launch a satellite, *Alouette 1*.
- When *Apollo 11* made its historic first manned flight to the Moon in 1969, landing gear built in Canada ensured that the astronauts would safely touch down.
- The first Canadian in space was Marc Garneau, who participated in the space shuttle mission in October 1984.
- Roberta Bondar was the first Canadian female astronaut to fly on a shuttle mission, in 1992.
- Canada provided technology for the *Mars Pathfinder* mission. It was a Canadian-designed ramp that the *Sojourner* rover rolled down in 1997.
- In April 2001, Chris Hadfield became the first Canadian to walk in space when he helped deliver Canadarm 2 to the International Space Station.

reSEARCH

Which Astronaut Is She?

In the early summer of 1999, this astronaut became the eighth Canadian in space. She was the second Canadian female astronaut and only one of three Canadians to operate the robotic space arm. Find out who she is and how she became an astronaut. Begin your research at www.pearsoned.ca/scienceinaction.

CHECK AND REFLECT

Key Concept Review

1. When was Canada's satellite *Alouette 1* launched? What was unique about it?
2. What was Canada's technological contribution to the shuttle program?
3. What is the common name of the Canadian-designed and -built Remote Manipulator System on the International Space Station?
4. Name one of the unique qualities of the Remote Manipulator System.

Connect Your Understanding

5. What Canadian technology contributed to the success of the Moon expedition in 1969?
6. What was the Canadian contribution to the *Mars Pathfinder* mission?
7. Using information provided in section 4.2, create a timeline depicting Canada's contributions to space exploration.

Extend Your Understanding

8. Would the Canadarm 1 design be suitable for the International Space Station? Explain your answer.
9. Imagine that NASA had a lottery in which the first prize was a ride in the shuttle. There would be no training, or studying at all. The winner would simply join the shuttle astronauts the next day for a launch into space. List several reasons why this would be a foolish venture for the individual who won and for the space agency.

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The Moon and Life Support

Volcanic material on the Moon contains trapped oxygen. Some scientists believe that heating this material would allow the oxygen to be released and captured. They also believe that both oxygen and water could be extracted from the ice at the lunar poles. "Mining" the oxygen and water in this way could support future long-term settlement by humans.

4.3 Issues Related to Space Exploration

Debate rages today over the huge amounts of money, time, and resources that are being expended on sending equipment and people into space. In the United States and Canada alone, the space program costs billions of dollars every year.

THE PROS AND CONS OF SPACE EXPLORATION

Some people argue that, because there are so many problems on Earth to be solved (such as poverty, hunger, pollution, and disease epidemics), countries should not be spending huge sums of money to explore new regions. Instead, they say, that money should go to relieving the suffering of citizens on our own planet. Other people argue that space is the "last great frontier," and that what we learn by exploring it could help us find ways of improving life on Earth.

Figure 4.10 How do you think money and resources should be spent: to address problems on Earth, or to explore space?

These and other factors must be taken into account when decisions are being made about the future of space exploration and development.

Some forecasters suggest that the population of Earth will continue to increase for the next 50 years before stabilizing. This increase, combined with continued growth in our standard of living, means that the demand for natural resources (such as minerals and fossil fuels) will rise. Instead of looking to Earth to find more of those resources, technology is allowing scientists to look to space for them.

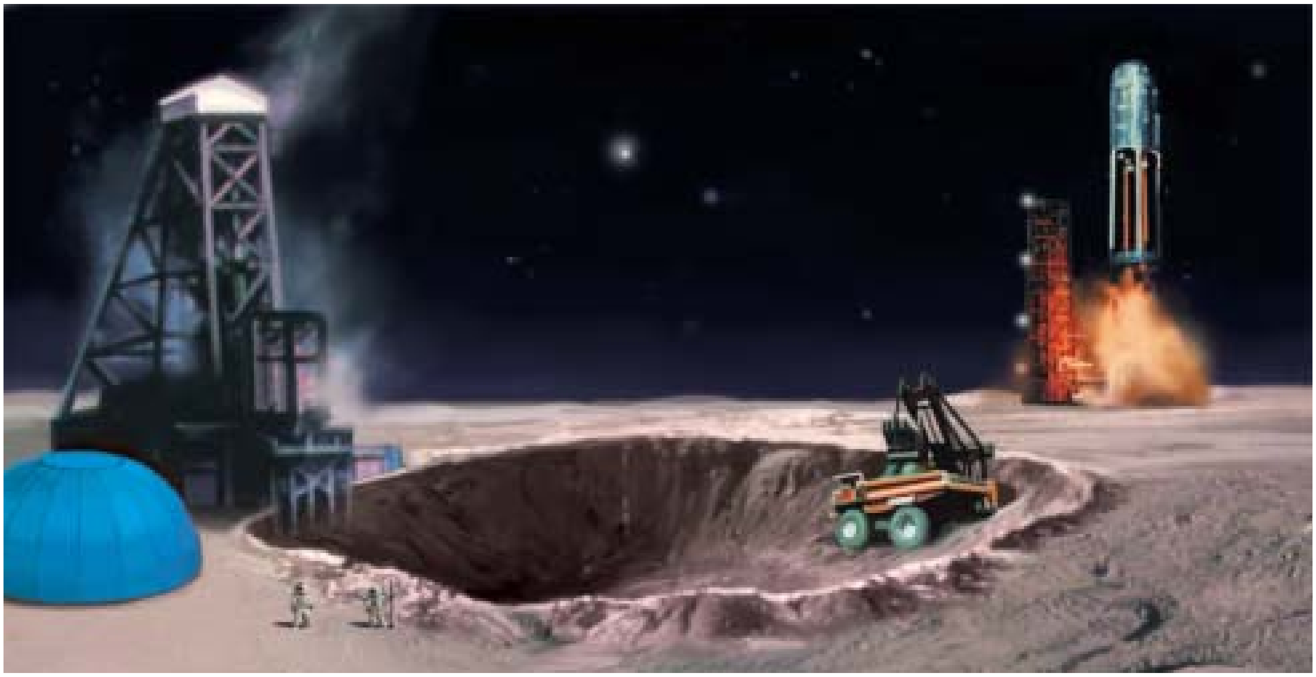

Figure 4.11 As technology has allowed us to study and navigate space safely and efficiently, we have discovered that space is not a barren place. With the right technology, many valuable resources may be readily available.

THE POTENTIAL VALUE OF SPACE'S RESOURCES

Why would we even need to use resources from space? The reasons are economic.

First, with the resources space has to offer, our energy needs on Earth could be satisfied for a long time. For example, scientists are looking for ways of capturing solar energy in space and beaming it to Earth. As well, space is a boundless source of mineral resources. The asteroid belt that lies between Mars and Jupiter, for instance, contains hundreds of thousands of rocky chunks floating in space. Asteroids have been found to contain iron, as well as gold and platinum group metals. At present market value, a 200 000-t asteroid would yield more than $350 billion worth of mineral resources.

Second, the cost of space travel could be cut substantially. It costs a great deal of money to transport fuel and materials from Earth into space. If materials for the construction of space vehicles, supplies, and fuel can be found where they are to be located in space, costs would be reduced.

The first place scientists looked for resources in space was our closest neighbour, the Moon. Both hydrogen and oxygen can be easily processed from Moon rock. The hydrogen could be used as fuel for lunar bases and space travel. The oxygen could be used for life support. Combine the two and you have a readily available supply of water. Our Moon is not the only source of material. Phobos and Deimos, the moons of Mars, could be used to supply shuttles to that planet.

ACTIVITY E-8

Decision Making

SHOULD WE CONTINUE INVESTING IN SPACE EXPLORATION AND RESEARCH?

The Issue

Every year, there are new, bold projects proposed for the study and exploration of space. Humans continue to push the boundaries of the imagination, from building more sophisticated satellites to planning manned space flights to Mars. Ultimately, we will not be limited by our creativity, but by our ability and willingness to pay for costlier ideas.

Background Information

Throughout this unit, you have learned a great deal about the progress of technology designed to enable us to observe and explore space. You have seen how space research has helped people directly (for example, with satellite communications) and indirectly (with spin-offs such as protective clothing and health care equipment). In this section, you are learning about the great cost of space exploration and the many risks. Should we continue investing in space? Can we afford to keep doing it? Can we afford not to?

1. Working in small groups, brainstorm the pros and cons of human investment in space endeavours.
2. Research each of the items on your list in more detail, using such sources as the Internet, books, magazines, journal articles, and local experts.
3. Individually, summarize your findings in a short report. Conclude the report by stating whether you agree or disagree with humans continuing to invest in space exploration and research. Explain your view. Be sure to consider observations and ideas from a number of sources before drawing your conclusions.

Analyze and Evaluate

4. Present your findings and position on the issue to the class. Be prepared to defend your opinions using the results of your research. Use any format you wish (for example, posters, flip chart, handouts) to communicate your ideas.
5. Listen to your classmates' presentations and be ready to ask questions based on your research.
6. After all the presentations have been made, re-evaluate your position on the issue. Did any of the arguments made by others who held the opposite point of view to yours make you want to reconsider your view? Explain why or why not.

Figure 4.12 Debate the issue of investing in space exploration and research.

POLITICAL, ETHICAL, AND ENVIRONMENTAL ISSUES

Although it is widely agreed that valuable resources can be found in space, who owns them and who has a right to use them will become major matters of debate in future plans related to space development. There are also ethical and environmental issues to consider, as the table below summarizes.

Issues		
Political	**Ethical**	**Environmental**
• Who owns space? • Who has the right to use the resources in space? • Who will determine how space will be used?	• Is it right to spend money on space exploration rather than on solving problems on Earth? • Do we have a right to alter materials in space to meet our needs? • How can we ensure that space resources will be used for the good of humans and not to further the interests of only one nation or group?	• Who is responsible for protecting space environments from alteration? • Who is responsible for cleaning up space junk, and who should pay for doing it?

math Link

The Value of an Asteroid

Find out what minerals an asteroid contains, and research the current market value ($) of each mineral. Using that information, calculate the value of an asteroid if it yielded 100 000 t of minerals. Assume that all the minerals found in the asteroid exist in the same proportion (e.g., five minerals, each 20 000 t = 100 000 t).

GIVE IT A TRY

WHO OWNS SPACE?

As travelling into space becomes safer, easier, and more economical, questions arise about the nature of our journeys. In this activity, you are asked to consider some ethical issues on the exploration of space. In a small group (three to four students), discuss the following questions. One person should record the group's ideas.

1. Are the resources of a moon, planet, or asteroid the property of the first nation to land on it or claim it?
2. Should space resources be owned only by nations rich enough to be able to afford the costs of reaching the site of those resources?
3. If we journey to other planets, should we go as eco-tourists, only to observe the planet, leaving it in the condition we found it, or as pioneers, to settle and change the planet to meet human needs?

When you have finished your discussion, compare your group's ideas with those of the other groups in the class. Be prepared to defend your position on each question.

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Moon Marketing
Use the Internet to find out who the entrepreneurs are who are advertising trips to the Moon. Begin your research at www.pearsoned.ca/scienceinaction.

On Earth, similar issues were debated over Antarctica. Though not to the same degree as space, Antarctica is a hostile, remote environment that has valuable resources. No one country, however, could lay claim politically to those resources for itself. In 1959, however, the 12 nations that had bases on the continent signed a treaty to share the resources of the area. Part of the Antarctica Treaty System reads, “Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord.” The concept requires that all nations work collaboratively to resolve differences. A space treaty could have the same requirements.

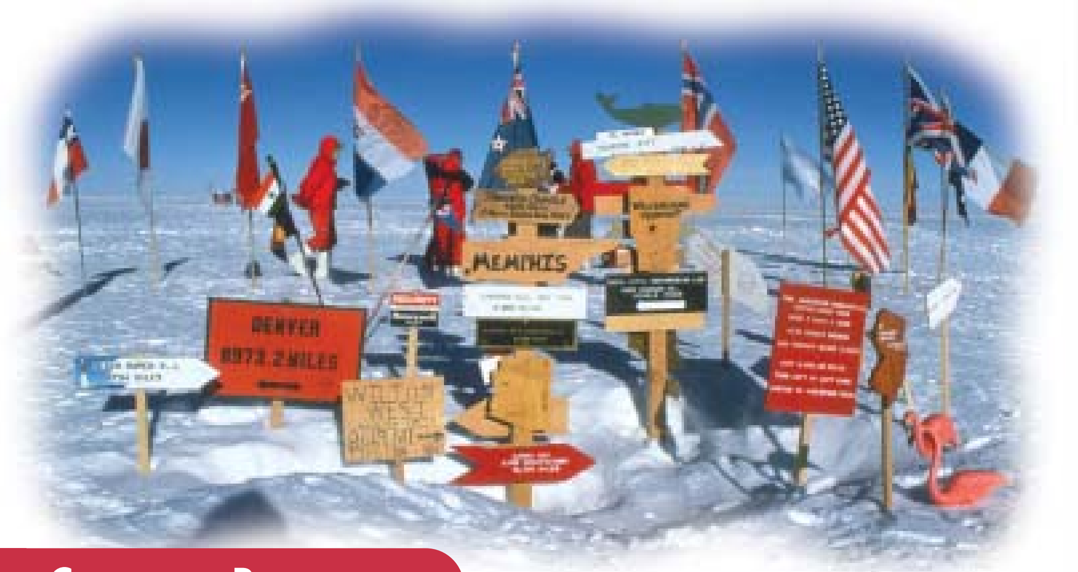


Figure 4.13 The flags of many nations are planted at the South Pole.

CHECK AND REFLECT

Key Concept Review

1. Why might asteroids be of interest in space exploration?
2. What two elements can be processed from material on the Moon?
3. How could the elements processed from Moon-material be used?
4. Name two concerns that some people have about exploiting resources in space.

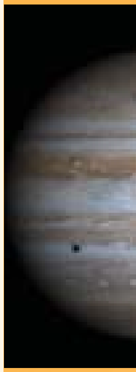
Connect Your Understanding

5. How do left-over materials in space pose a threat to people on the ground?
6. Explain a political concern that exists about space and its resources.
7. Describe an environmental concern about the exploration and exploitation of space.

Extend Your Understanding

8. List three costs of space exploration, and three benefits.
9. Give two reasons why resources should be extracted and processed in space. Give two reasons why they shouldn’t.

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. Describe three major hazards that astronauts could encounter on their journey from Earth to the International Space Station.
2. Suggest one solution to the space junk problem.
3. List two benefits of Canada collaborating with other countries in space exploration.
4. How are the exploration of Antarctica and the exploration of space similar?

Connect Your Understanding

5. Sixteen different nations are represented in the International Space Station. In your view, who owns space and the resources found there?
6. Besides space junk, give another negative effect of space exploration.
7. Why would mining asteroids or the very small Martian moons be more appealing to a mining company than mining on Mars itself?

Extend Your Understanding

8. Describe a way in which space exploration could benefit all people on Earth.
9. In point form, write your own space treaty. Consider the ethical, political, and environmental issues involved in the exploration of space.

Focus On SCIENCE AND TECHNOLOGY

Fulfilling the dream of human exploration of space only makes sense if it can be done safely, economically, and in a socially and ethically acceptable way. Technological advances, some contributed by Canadian scientists, have made it easier to send people and materials into space. However, as has always been the case in the past on Earth, colonizing new environments leads to dramatic changes. As human influence spreads throughout the solar system and beyond, issues such as ownership, stewardship, and ethical responsibility must be addressed.

1. How has the advancement of technology made space travel safer?
2. Why is it advantageous for Canada to contribute space technologies to international projects rather than to pursue space exploration by itself?
3. As technology makes it easier for humans to get into space, what issues about ownership must be addressed?

UNIT SUMMARY: SPACE EXPLORATION

Key Concepts	Section Summaries
1.0 • technologies for space exploration and observation • reference frames for describing the position and motion of bodies in space • distribution of matter through space • composition and characteristics of bodies in space	**1.0 Human understanding of both Earth and space has changed over time.** • Ancient cultures explained their observations of bodies in space with myths and legends. • Technology used to study space has evolved throughout history. With each technological advance came better explanations for what was observed. • The planet Earth orbits a star that is one of billions of stars in a spiral galaxy called the Milky Way. • Years of accurate data collection and advances in telescope technology have improved our scientific understanding of the solar system. • A star's position when viewed from a particular point, can be determined given the compass direction (azimuth) and the altitude.
2.0 • technologies for space exploration • life support technologies • communication technologies	**2.0 Technological developments are making space exploration possible and offer benefits on Earth.** • Space transport technology began with simple rockets, and today's spacecraft are still launched using the same principles. • For humans to live outside of Earth's atmosphere, the basic requirements for life must be met in space. This means that food, shelter, water, and air must be produced artificially. • Satellites orbiting Earth transmit information to us about weather, agriculture, and natural resources. We can also use space technology to locate our exact position on Earth. • Many concepts designed for use in space have found applications on Earth. These include materials used for communication, medicine, entertainment, and transportation.
3.0 • technologies for space exploration and observation • composition and characteristics of bodies in space • communication technologies • triangulation and parallax	**3.0 Optical telescopes, radio telescopes, and other technologies advance our understanding of space.** • Reflecting and refracting are two types of optical telescopes. Reflecting telescopes use mirrors to focus light. Refracting telescopes use lenses to focus light. • Visible light is only one part of the electromagnetic spectrum. This spectrum includes infrared, X-ray, ultraviolet, and gamma radiation. Specific technologies are designed to detect these forms of radiation that come to us from space. • By observing the shift in the spectrum of a star, we can tell if it is moving toward or away from Earth. • Triangulation and parallax are two techniques for measuring distances in space.
4.0 • space exploration risks and dangers • technologies for space exploration and observation • life support technologies • ownership and use of resources in space	**4.0 Society and the environment are affected by space exploration and the development of space technologies.** • There are many dangers associated with both manned and unmanned space exploration. Some of those dangers are posed by debris floating in space around Earth and by solar and cosmic radiation. • Canada has had a long and proud history of participation in space research and exploration. • Many issues concerning ownership of space and its resources are yet to be resolved. These include political, environmental, and ethical issues.

Babies Beyond Gravity's Grip

The Issue

The International Space Station is just the first step in human colonization of space. In the not-too-distant future, permanently manned space stations and bases on the Moon are likely to be the next step in space exploration. Some scientists predict that within two decades, the first inhabited colony on Mars will be established. The first colonists will probably include families, which means that babies might, for the first time ever, be born in a place other than on Earth. Numerous health, social, and emotional issues would surround such a significant historical occurrence.

Physical Health Issues	• How would the space environment physically affect a new baby? • Are there concerns other than microgravity that could affect the health of a developing baby? • How would a child born and raised on the Moon, Mars, or an orbiting space station be physically affected by moving to Earth?
Social Issues	• What would be the nationality of a baby born in space? • What nation would be responsible for providing the child with any social and medical support it needed? • How socially connected to Earth would a person raised in space feel?
Emotional and Psychological Issues	• How would living in small, cramped conditions with limited freedom to move around affect a young child growing up? • What effects, if any, would a child experience from living apart from a natural environment that has air, grass, trees, rain, and birds? • How would a child who is born and raised on the Moon, Mars, or an orbiting space station be emotionally and psychologically affected by moving to Earth?

Go Further

Now it's your turn. Look into the following resources for information to help you form an opinion about what health issues might affect babies and children raised away from Earth.

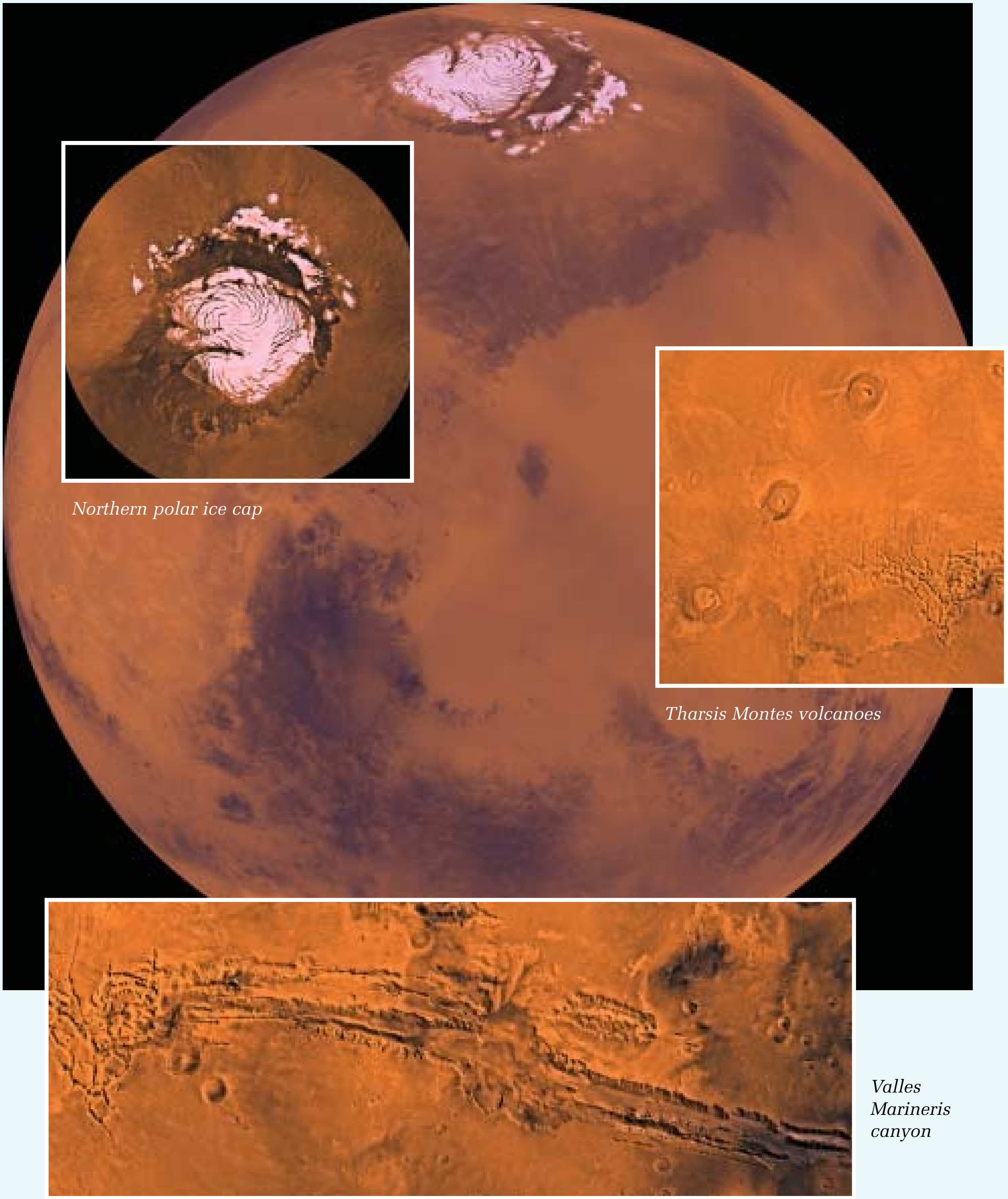
- Search the Web: Check the Internet for information about space travel and the effects of microgravity on the human body.
- Ask the experts: Talk to a doctor or a nurse at your local hospital or medical clinic about how microgravity conditions would affect the development of a baby and child.
- Check journals and magazines: Search for current stories related to travelling in space for long periods and the effects of low to microgravity.

Analyze and Address the Issue

Imagine you were one of the first children to be born in space. (Assume for this case study that, thanks to technological advances, conditions for safe delivery were created for you and your mother.) Your life so far has been spent in space, but now, as a young teenager, you are moving to Earth. Write a series of first-person diary entries chronicling your adjustment to Earth. Start with your first day arriving on the planet. Compare and contrast your life in space with your life on Earth, and consider both the emotional and physical impacts. Be sure to use your research material to support your ideas.

PROJECT

MISSION TO MARS



Northern polar ice cap

Tharsis Montes volcanoes

Valles Marineris canyon

Getting Started

We have learned much about Mars from telescopes, robotic probes, and satellites, but to really understand the nature of the planet, we will have to see it for ourselves. This project will allow you to apply what you have learned in this unit about space exploration, the requirements of living in space, and the way in which technology and science go hand in hand to advance our knowledge about the universe. You will be designing the first mission to Mars. Where you land is up to you. You can choose between the Valles Marineris canyon, the Tharsis Montes volcanoes, and the northern polar ice cap.

Your Goal

The project has three parts.

- First, design an unmanned probe that will safely touch down and explore the target area on Mars that you have selected.
- Second, design a base camp for a team of eight astronauts (four women and four men) who will be the first humans to colonize Mars. Scale models must be made for both the probe and the base camp.
- Third, decide which feature to study and how.

What You Need to Know

The mission to Mars will last approximately 22 months. That time includes the eight months it will take to travel there, six months to explore the surface, and eight months to return to Earth. In addition to what you learned about the nature of Mars in subsection 1.4, you should keep in mind that dust storms with winds up to 900 km/h can cover most of the planet for weeks. Also, communication signals from Mars can be expected to take about 8 min to reach Earth. Your base camp design must include laboratories, food, water and air supplies, and living space. It must also reflect which feature your mission is going to study and how.

Steps to Success

1. Working with two or three partners, select the area of Mars that will be the focus of your mission. Brainstorm ideas for both the type of landing probe you wish to design and the style of base camp. Using a variety of sources, research the characteristics of the surface feature your mission is going to study. With your partners, identify problems resulting from the conditions on Mars and discuss possible design solutions.
2. Complete two scale drawings, one for the probe, and one showing the layout of the base camp. Include ideas about how the astronauts will travel on the surface of the planet.
3. Construct scale models of your probe and the base camp using materials of your choice.
4. Write descriptions of a) the tasks to be performed during the mission, b) the features of your landing probe, and c) the features of your base camp.
5. Present your work to the class and explain the rationale behind your designs.

How Did It Go?

6. In your notebook, answer each of the following questions in a paragraph.
   a) How did your research influence your design for each part of the mission?
   b) Did you use current technology, or did you design your own technology to meet the needs of the mission?
   c) How effective was the group decision-making process? How were disagreements resolved?
   d) After seeing your classmates' presentations, are there any changes you would make to your designs? Explain your answer.

UNIT REVIEW: SPACE EXPLORATION

Unit Vocabulary

1. Make a brief sketch that illustrates each of the following vocabulary words or terms:
geocentric
heliocentric
elliptical
black hole
constellation
galaxy
solar system
comets
meteors
astronomical unit
light-year
Hubble Space Telescope
spectrum
space junk

Key Concept Review

1.0

2. What information did constellations provide early sky-watchers?

3. What is the first stage in a star's life called?

4. All stars start from the same "building blocks." What element forms these building blocks?

5. Define a light-year.

6. a) How many stars are estimated to be in the Milky Way galaxy?
b) How many galaxies are estimated to be in the universe?

7. Explain why you could not locate a star by knowing only its altitude in the sky.

2.0

8. Draw a rocket and label its main parts. What propels a rocket forward?

9. List five basic requirements for humans living in space.

10. Describe some of the effects on the human body that result from living in microgravity .

11. How does the Global Positioning System work? Illustrate your answer.

12. Name four materials or items we use on Earth that were originally designed for use in space.

3.0

13. What part of the electromagnetic spectrum can humans detect?

14. Explain how astronomers use multiple small telescopes to imitate one large telescope.

15. What is the Doppler effect and how is the principle applied in determining star motion?

16. Explain how the process of triangulation can determine distances on the ground.

17. What aspect of Earth makes it difficult to observe the X-rays, gamma rays, and ultraviolet rays that come from space?

4.0

18. Name four risks associated with space exploration.

19. List three different contributions Canada has made to the space industry.

20. Why is space junk an issue in space exploration?

Connect Your Understanding

21. Describe what you consider to be the most important issues facing space exploration.
22. Describe how space exploration, or its spin-off products, have affected you personally.
23. In the late 1970s, when Skylab was due to re-enter Earth's atmosphere, insurance companies were offering policies to insure people who might get hit by pieces of the space station that reached Earth's surface. Explain why it would be highly unlikely for anyone to ever need to use such an insurance policy.
24. If space technology and exploration affect the planet as a whole, how should decisions regarding their use be made?

Extend Your Understanding

25. Explain why looking at stars in the night sky is considered looking into the past.
26. As soon as a comet gets close enough to the Sun to feel the Sun's effects, the gases in the comet begin to bubble (effervesce) and it leaves a trail along the path it has followed. When a comet's tail is visible, it always points away from the Sun. Explain why this occurs.
27. If we knew a galaxy was moving away from Earth, but we see a star in the galaxy with a spectrum shifted towards the blue, what would we conclude?

Practise Your Skills

28. Sketch a diagram that illustrates your understanding of the differences between reflecting, refracting, and radio telescopes.
29. Construct a Venn diagram that compares and contrasts the characteristics of Mars and Earth.
30. Sketch how an ellipse changes in shape when the foci (the two pins that you used in the activity on page 375) are moved farther apart from each other. Relate this to the orbits of planets around the Sun.

Self Assessment

31. Describe three facts that you found most interesting in this unit which you did not know before.
32. What are two questions that you have about technology used for space exploration and travel?
33. Has your opinion about the value of space exploration changed in the course of reading this unit? Explain your answer.
34. Which spin-off of the space industry has had the greatest effect on your life?

Focus On SCIENCE AND TECHNOLOGY

In this unit, you have investigated science and technology related to space exploration. Consider the following questions.

35. As improvements are made to technology, our understanding of the universe around us advances. Should decisions that could potentially affect the entire planet be made by only a handful of scientists? Explain your answer.
36. Describe three ways in which the technology from space exploration has potential to benefit all people in the future. What drawbacks to the development of this technology can you think of? Give reasons to support your answer.
37. When making decisions about space exploration and the exploitation of resources in space, what do you feel are essential questions to ask?