Chapter 11

We continue to learn a lot about the solar system by using space exploration.

In the past 50 years, humankind has taken the first steps off planet Earth into the solar system. For centuries, astronomers have learned about our solar system by observing it through telescopes based on Earth's surface. Now our views of the planets are much improved by using space-based telescopes and space probes. Canada has been a space-faring nation from the beginning, building satellites and robotic arms and sending Canadians into space. What have we learned? How has life on Earth changed as a result of these new observations?

What You Will Learn

- **describe** the features of the Sun
- **compare** the inner and outer planets
- **identify** a range of instruments and tools used in astronomy
- **describe** Canada's participation in space exploration

Why It Is Important

Understanding the characteristics of the Sun and the other planets in our solar system help us to better understand our own planet Earth. Human society continues to benefit immensely from technologies originally developed for exploring space.

Skills You Will Use

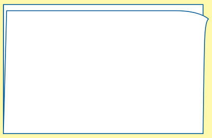
In this chapter, you will:

- **determine** the rotation rate of the Sun
- **observe** the planets using a telescope
- **design** a space station
- **model** the results of meteorite impacts

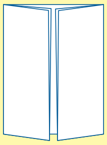
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 11.

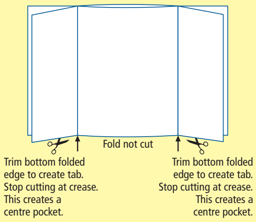
STEP 1 **Fold** a large sheet of paper in half.



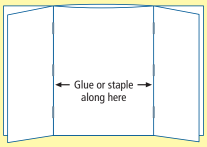
STEP 2 **Fold** it into a shutterfold as shown.



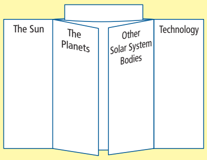
STEP 3 **Cut** away the fold on the bottom left and bottom right sides of the shutterfold; do not cut the fold in the centre of the Foldable.



STEP 4 **Glue** or **staple** along the left and right fold lines to form a large pocket in the centre of the Foldable.



STEP 5 With the side tabs closed, write the title of the chapter across the front tabs. Open the tabs and label the inside left tabs "The Sun" and "The Planets". Open and label the inside of the right tabs "Other Solar System Bodies" and "Technology."



Note-taking Skills Use this Foldable to practise note-taking skills and to organize main ideas, supporting facts, diagrams, self-questions, terms, and definitions you encounter in the chapter. The pocket can hold notes and worksheets collected during the study of this chapter.

11.1 The Sun and Its Effect on Earth

The Sun provides us with all the heat and light to make life possible. It has many other effects on Earth—from beautiful northern lights to intense solar storms which can damage Earth-orbiting satellites and Earth-based power systems. Scientists have learned a lot about average-sized stars by studying our own Sun.

Key Terms

chromosphere
corona
photosphere
solar prominences
solar radiation
solar wind
space weather
sunspots
thermonuclear reaction

Word Connect

The term "solar" comes from the Latin word *solaris*, which means of the Sun.

The Sun is millions of kilometres away from Earth. Yet we experience its effects every day of our lives. The food we eat depends on energy from the Sun (Figure 11.1). Our eyesight relies on light from the Sun. The gasoline in cars and buses comes from fossilized plants that originally grew with energy from the Sun. Think about what you have done today. In what ways did your activities depend on the Sun?

Figure 11.1 Without the Sun, Earth could not sustain life. But we also need to be careful of some of the Sun's effects.

The Sun

The Sun is an average-sized star. It contains more than 300 000 times more mass than Earth. Strong gravitational forces pull the Sun's huge mass toward its centre. This process generates great pressure and heat at the centre of the Sun. The pressure and heat, in turn, trigger thermonuclear reactions. In a **thermonuclear reaction**, two or more atoms fuse, or combine, to create a different, larger atom, plus a tremendous amount of energy in the forms of heat, light, and other electromagnetic radiation. In the Sun, four hydrogen atoms fuse to form helium as well as the electromagnetic energy that we see as light and feel as heat millions of kilometres away on Earth. Because we know how much hydrogen is in the Sun and the rate at which hydrogen is used up in the core of the Sun, scientists have calculated that the Sun has been giving off heat and light for 5 billion years and it has enough hydrogen to last another 5 billion years.

There is a tug of war going on inside any star, including our Sun. The force of all the material trying to collapse the star is equally balanced by the force of **solar radiation** moving out from the core of the star. These forces are balanced and the star continues to shine for as long as the hydrogen fuel lasts.

Fortunately for us, the Sun has given off a steady amount of heat and light for billions of years. This process has allowed life on Earth to flourish. Earth is in an orbit that is not so close to the Sun that it becomes a scorched ball of rock; nor is it so far away that it becomes an icy wasteland. It is situated in what astronomers call the Goldilocks zone—not too hot, not too cold, and just right.

At first, astronomers studied the Sun using telescopes on Earth's surface. Over the past few decades, technology has enabled scientists to monitor the Sun from observatories in space (Figure 11.2).

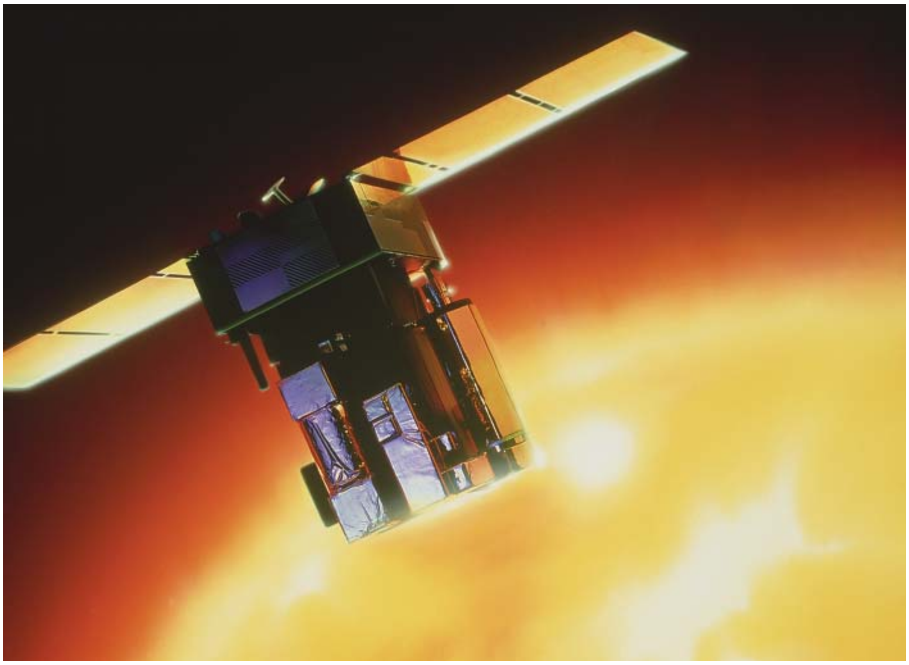


Figure 11.2 The Solar and Heliospheric Observatory (SOHO) has been observing activities on the Sun since 1995.

Features of the Sun

Even though our Sun is just a star of average size, it would take about 110 Earths lined up side-by-side to match the Sun's diameter. The Sun contains more than 99 percent of all the mass in the solar system, equal to almost 100 times the mass of all the planets combined. Most of the Sun's mass is hydrogen gas, the most common element in space. As in all stars, thermonuclear reactions in the Sun's core cause this hydrogen to fuse to create helium. The tremendous radiated energy that is produced keeps Earth warm enough to support life.

Did You Know?

The Sun contains 2×10^{33} or 2 billion trillion trillion g of matter—90 percent of which is hydrogen. Even though the thermonuclear reaction converts 626 billion kg of hydrogen into helium every second, there is enough hydrogen to fuel this reaction for 10 billion years.

Explore More

As well as heat and light, the Sun is a source of ultraviolet radiation. The thinning of the ozone layer that surrounds Earth will allow more of this potentially harmful radiation to reach Earth's surface. Research the impact that this radiation will have on people, animals, and crops. What techniques and technologies have been developed to protect us from ultraviolet rays?

Suggested Activity

Conduct an Investigation 11-1A on page 395

Although the Sun appears to be a quiet, unchanging presence in our sky, the opposite is true. The Sun can become quite active and violent, ejecting large amounts of solar radiation into the solar system. The Sun is a complex system of bubbling gases that occasionally sends out spectacular explosions and violent solar flares. It has no solid surface but many distinctive features, as shown in Figure 11.3.

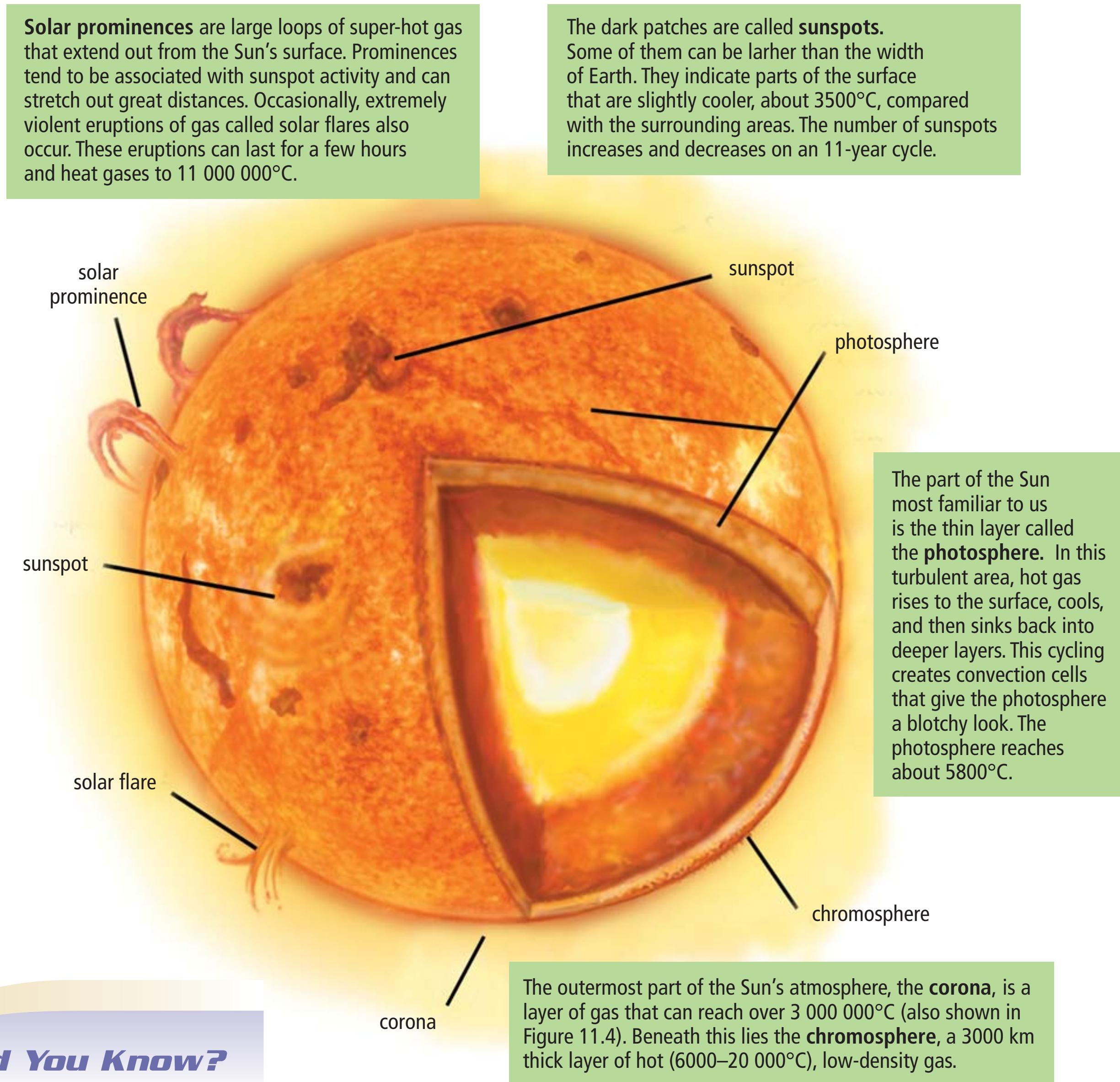


Figure 11.3 The main features of the Sun

Did You Know?

The number of sunspots on the Sun may affect Earth's climate, although it has not been proven and scientists are still debating the theory. There are records that show a lack of sunspots during much of the 17th century, when Europe experienced a mini Ice Age.

Figure 11.4 The Sun's silvery solar corona is easily visible during the brief period when the Moon totally covers the Sun during a total solar eclipse.

Figure 11.5 A spacecraft in Earth orbit took this picture of great looping arcs of hydrogen gas rising over the Sun. An image of Earth has been placed in the picture to give an indication of the immense size of the arcs.

Solar Wind

Sometimes the hot and energetic gases in the Sun's corona get ejected in a sudden burst. Gas is spewed out in every direction, similar to what happens when a soap bubble bursts. When these high-energy particles rush past Earth, they create an effect called the **solar wind**. Exposure to solar wind could be fatal for any organism living on Earth. Fortunately, Earth's magnetic field deflects most of the solar wind around the planet, as shown in Figure 11.6.

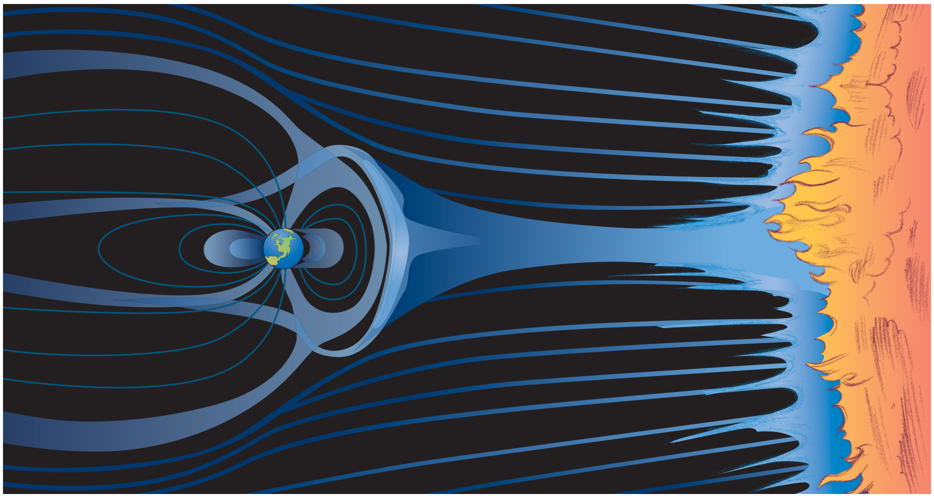


Figure 11.6 In this diagram, Earth's magnetic field forms a shield that helps to deflect the dangerous radiation in the solar wind.

Some of the high-energy particles in solar wind enter Earth's atmosphere at the North and South Poles, where they collide with gases in the atmosphere. The results are the extraordinary light shows in the sky that we call the auroras, or the northern lights and southern lights (Figure 11.7 on the next page). The colours that can often be seen in these lights depend on which gases collide with the particles. The solar wind can also generate powerful geomagnetic storms, or disturbances in Earth's magnetic field, which can disable satellites and knock out power transmission lines on Earth. Intense solar storms can expose astronauts to dangerous if not lethal doses of radiation. Although shielding is built into space shuttles and the space station, astronauts are still exposed to more radiation in space than they would ever receive on Earth.

Figure 11.7 The solar wind is responsible for creating the incredible displays of lights we call aurora borealis and aurora australis.

Space Weather

Just as we monitor the weather on Earth so that we can plan activities and any protective measures we need to take, astronomers monitor the effects of the Sun on the inner solar system, especially its effects on Earth. These effects are called **space weather**. Spacecraft in orbit around Earth watch for potentially dangerous outbursts and the results are posted on websites. If a solar storm knocks out a communication satellite, it can have a devastating effect on global communications.

internet connect

Just like you can check the weather near your home on the Internet, there are websites that provide information about space weather. Find out more about what types of data are included. Visit **www.discoveringscience9.ca**.

Reading Check

1. What are three effects that the Sun can have on Earth?
2. What material makes up most of the Sun's mass?
3. What is the name for the dark areas on the photosphere of the Sun?
4. Define solar wind.
5. (a) What are the names of the light phenomena that occur in the sky at the North and South Poles?
   (b) Explain why these lights occur.

11-1A Observing Sunspots

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Performing and recording
- Analyzing and interpreting
- Communicating

Safety

- CAUTION: Never look through a telescope or binoculars when they are pointed at the Sun.

Materials

- Astroscan telescope and/or pair of binoculars with lens caps
- light surface, such as a white piece of paper
- clipboard

Sunspots are magnetic storms in the Sun's photosphere. They are cooler than the surrounding area and therefore appear dark. While you should never look directly at the Sun, you can safely view the Sun if you project the image of the Sun onto a light surface—such as a white screen, a light wall, a pillowcase, or the sidewalk.
In this activity, you will observe the Sun's image and estimate when the sunspots you observe will reappear.

Question

What patterns can you observe in the locations of sunspots?

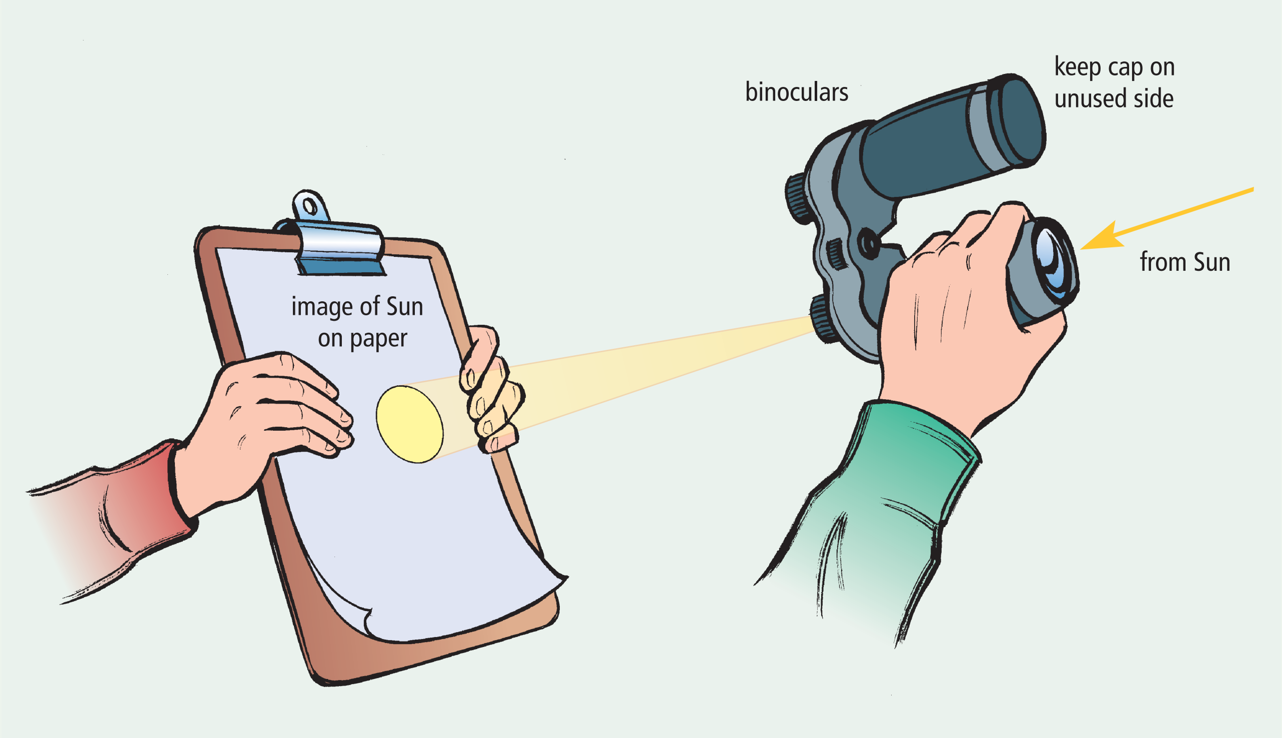
Procedure

1. Find a location where the image of the Sun can be projected at the same time of day for five days.
2. If you are using the Astroscan telescope, point it in the general direction of the Sun. **Do not look through the eyepiece.** Adjust the telescope while looking at the shadow it is making on the solar viewing screen. (You should be able to tell when the telescope is pointing at the Sun by the size of the shadow. When the shadow is the smallest, the telescope should be pointing at the Sun.) Adjust the focus on the telescope until you have a clear image on the solar viewing screen. Go to step 4.

Astroscan telescope

11-1A Observing Sunspots

3. If you are using binoculars, attach a piece of white paper to a clipboard. Put one lens cap on one of the binocular lenses. Your partner will hold the binoculars as shown in the diagram below. You will hold the clipboard. Move the clipboard back and forth until you have the largest possible image of the Sun on the paper. Adjust the focus on the binoculars until you have a clear image on the paper.



4. Trace the image of the Sun and the images of any sunspots that appear on the Sun. Repeat this step at the same time each day for five days if possible. If you are using the Astroscan, take a photo of the image with a digital camera.

Conclude and Apply

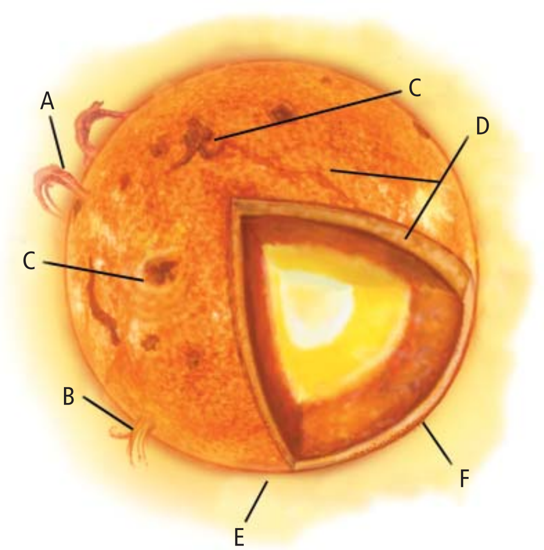
1. Did the sunspots change in appearance or location from day to day? If so, how?
2. Predict how many days it will take for the same sunspot or group of sunspots to return to the same position in which the sunspot or group of sunspots appeared on day 1.

Check Your Understanding

Checking Concepts

1. (a) What causes thermonuclear reactions?
   (b) What chemical change occurs during a thermonuclear reaction?
   (c) What are the effects of a thermonuclear reaction?
2. How has the Sun helped support life on Earth?
3. Use the diagram below to copy and complete the following chart. Identify the features of the Sun and summarize the physical characteristics of each feature.

Feature of the Sun	Characteristics
A.	
B.	
C.	
D.	
E.	
F.	



4. What is the hottest layer of the Sun?
5. Why would solar wind be fatal to organisms on Earth?
6. How is Earth protected from solar wind?
7. What causes the formation of the aurora borealis?

Understanding Key Ideas

8. How do scientists calculate the length of time the Sun has left to give off heat and light?
9. What forces must be balanced in order for a star to continue to shine?
10. Astronomers use the term "Goldilocks zone." What is the effect on Earth from the Goldilocks zone?
11. What gives the photosphere a blotchy look?
12. (a) What is meant by the term "space weather"?
    (b) What are some of the effects that a solar storm could have on global communication systems?

Pause and Reflect

It seems like the Sun has been around forever, unchanging, but that is not true. Scientists have observed that the Sun is actually slowly heating up. Every billion years it is becoming 10 percent more luminous. What could be the consequences of these changes on the existing forms of life on Earth?

11.2 Characteristics of the Celestial Bodies of the Solar System

Our solar system is full of planets, moons, asteroids, and comets, all in motion around the Sun. Most of these components are separated from each other by great distances. Each planet has its own distinct characteristics. Comets, icy debris, and dwarf planets travel at the outermost reaches of the solar system. Asteroids and large meteorites have impacted Earth over time, leaving craters of various sizes.

Key Terms

asteroid
astronomical unit
comet
dwarf planet
Kuiper Belt
meteor
meteorite
meteoroid
moon
Oort Cloud
planet
transit

Ever since Galileo pointed his telescope at Jupiter, the planets of our solar system have been targets for further study. As more powerful telescopes were developed, the views we had of the planets improved, and we were able to learn more about the different planets.

During the last half of the 20th century, an immense amount was learned about the solar system in other ways. As the technology for space travel developed, humans visited the Moon, and uncrewed robotic space probes were sent to all the planets. Some space probes made observations and then flew past the planets, leaving the solar system. Others went into orbit around a planet. By using radio communication, these probes were able to return high-quality pictures, much better than anything taken from Earth (Figure 11.8). Equipment on the probe was able to determine the composition of the planet and of its atmosphere. Robotic landers successfully landed on Venus and Mars and returned pictures of the surface. Two rovers travelled over the surface of Mars for over five years. The small moons that orbited some of the planets and appeared as small dots through the largest telescopes on Earth now took on a character of their own.

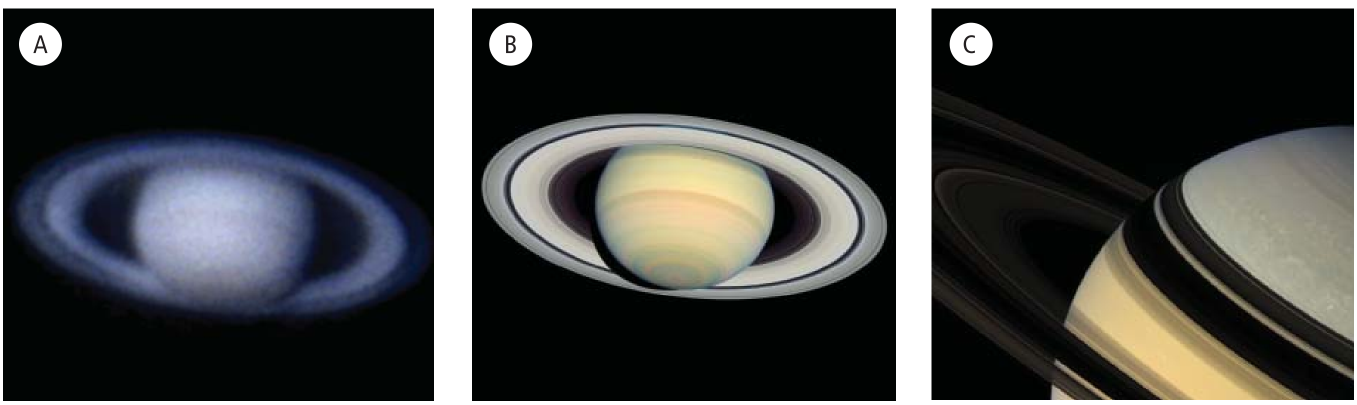


Figure 11.8 The planet Saturn as seen (A) through a small, Earth-based telescope, (B) through the space-based Hubble Telescope, and (C) from the *Cassini* spacecraft in orbit around the planet.

The Planets

To be considered a **planet**, a body must orbit one or more stars, be large enough that its own gravity holds it in a spherical shape, and be the only body occupying the orbital path.

Large distances keep our solar neighbourhood's family of eight planets well separated from each other (Figure 11.9). In fact, the planets lie so unimaginably far apart that kilometres are not a meaningful way of measuring distance, because the result is a huge, unwieldy number.

Figure 11.9 The planets, asteroids, and comets of our solar system are depicted in this artist's concept (not to scale).

Using kilometres to measure this great distance would be like using millimetres to measure the longest hallway in your school or describing the cost of everything in pennies only. For this reason, astronomers devised another unit of measure for solar-system distances. It is the **astronomical unit** (AU), and it is equal to the average distance between the Sun and Earth, about 150 million km. Therefore, Earth is 1 AU from the Sun, while Jupiter is 5.27 AUs from the Sun.

How did astronomers figure out the distance to the Sun? In the 1700s, Sir Edmund Halley proposed that the distance of the Sun could be determined by observing a transit of Venus. A **transit** takes place when a planet passes in between Earth and the Sun. Only transits of Mercury and Venus are visible from Earth (Figure 11.10). If the exact times that Venus appeared to move in front of and off of the Sun could be measured by several observers at different places on Earth, a value for the astronomical unit could be determined by using geometry.

The first opportunity to test this theory was in 1761. John Winthrop, an astronomer from Harvard College in Massachusetts, travelled to St. John's, Newfoundland, to observe the transit. Winthrop and two students set up their equipment on Kenmount Hill, which gave them a clear view of the rising Sun. Although beset by "swarms of insects that were in possession of the hill," Winthrop's team was successful in measuring the time when Venus moved off of the Sun's disc. When all the measurements came in, the distance to the Sun was calculated to be approximately 150 million km.

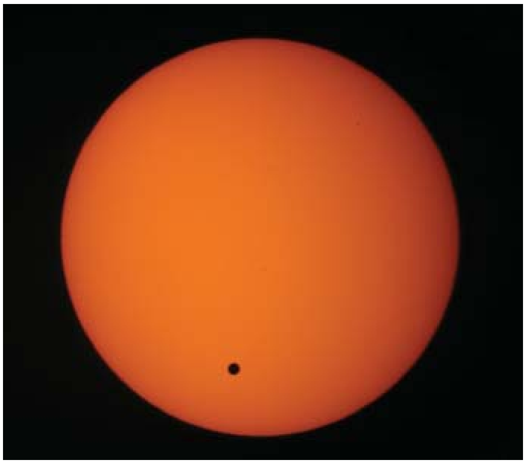


Figure 11.10 The 2004 transit of Venus was the first one visible since 1882.

Planet profiles

The planet profiles included on the next two pages will give you a better idea of your planetary neighbours.

Mercury

The closest planet to the Sun is also the smallest. Mercury is a rocky ball covered in meteor craters. It is slightly larger than our Moon and is about one third the size of Earth. It does not have any significant atmosphere. Mercury experiences extraordinary differences between night and day temperatures on its surface (ranging from 400°C to –183°C). This constant cycle of extreme heating and freezing causes the rock of Mercury to expand and contract, forming immense cracks in the surface.

Venus

Venus is often called Earth's sister planet because of its similar size and composition to Earth. A notable difference, however, is the atmosphere. The atmosphere of Earth provides oxygen and nitrogen. Venus's atmosphere is almost completely carbon dioxide. Surface features of Venus cannot be seen through optical telescopes because the planet is shrouded in thick clouds. Sulphur mixes with moisture in the atmosphere to rain down as sulphuric acid. In 1990, the *Magellan* spacecraft began scanning the surface of Venus using a radar probe. It revealed that large portions of the planet are very flat, while other areas have volcanoes, lava flows, and cracks called rifts.

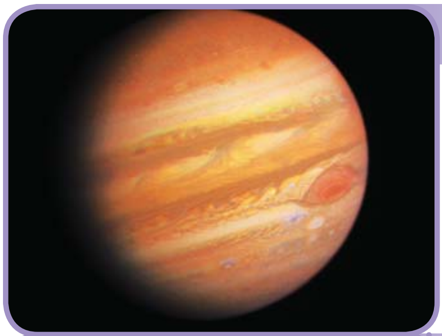
Earth

Our little blue planet, third from the Sun, is home to the only life yet discovered in the universe. Besides having a suitable atmosphere and temperature, Earth is the only place known to have water in three phases: liquid, solid, and gas. Water covers nearly three quarters of Earth's surface. Earth's atmosphere is composed mostly of nitrogen and oxygen, components essential to life. Running water, atmospheric effects, and plate tectonics together constantly shape the surface of Earth.

Mars

Mars is often called the red planet because the iron in its surface rocks gives it that colour. Despite being half the size of Earth, Mars has about the same amount of surface area. Several extraordinary features mark its surface, such as a volcano that is three times higher than Mount Everest and an 8 km deep canyon that would stretch from Vancouver to Toronto. Mars has a very thin atmosphere of carbon dioxide and can experience winds of more than 900 km/h. Dust storms can cover the whole planet and last for weeks. Mars has two polar ice caps made of frozen carbon dioxide and water. In 2008, the space probe *Phoenix* landed near one of these polar caps and discovered water ice on the planet's surface.

Planet	Average Distance from Sun (AU)	Radius (km)	Mass (relative to Earth)	Average Surface Temperature (°C)	Period of Rotation (relative to 1 Earth day)	Period of Revolution (relative to 1 Earth year)
Mercury	0.39	2 440	0.06	179	58.90	0.24
Venus	0.72	6 052	0.82	467	244.00	0.61
Earth	1.00	6 378	1.00	17	1.00	1.00
Mars	1.52	3 397	0.11	−63	1.03	1.70



Jupiter

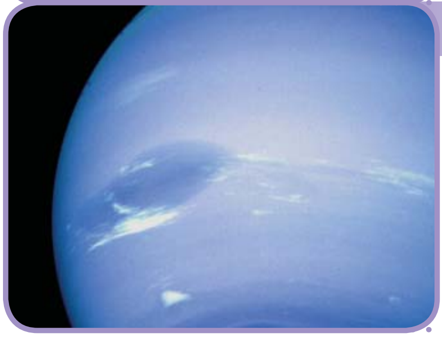
The largest planet in the solar system is Jupiter. It has a mass 2.5 times greater than that of all the other planets combined. Its "Great Red Spot" has been visible from Earth for more than 300 years. This spot, as large as three Earths, is a storm raging in the clouds of hydrogen and helium that form the planet's outer layers. Despite its immense size, Jupiter has the shortest day of any of the planets, turning once on its axis every 10 hours. If it were only 100 times more massive, Jupiter might have formed into a small, faint star.

Saturn

Saturn, another gas giant, is easily identified by its elaborate system of rings. Its rings are formed from ice particles rather than rocky chunks. Those particles range in size from specks of dust to the size of houses. The rings are 250 000 km wide but can be as thin as 10 m. A sheet of paper the size of a city would have the same thickness-to-width ratio as Saturn's rings. The planet itself is composed mainly of hydrogen and some helium.

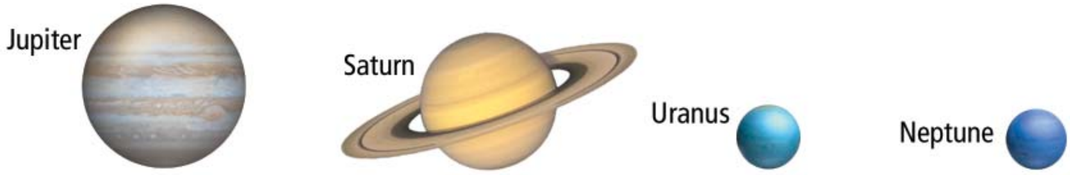
Uranus

Uranus is the fourth most massive planet in the solar system. A gas giant, it has a similar composition to Jupiter and Saturn, including a ring system composed of ice and dust. The planet gets its distinctive blue colour from the methane gas in its atmosphere (methane absorbs red light). Uranus has an unusual rotation in that it is flipped on its side. As a result, it appears to be rolling through its orbit around the Sun.



Neptune

Neptune is the outermost planet and the third most massive. Its composition is similar to that of Uranus, and it has the same dark blue colour. Like the other three gas giants, Neptune has a ring system, but it is very faint. When the *Voyager 2* spacecraft flew by Neptune in 1989, it discovered a large, blue, Earth-size patch on Neptune's surface. The patch, similar to Jupiter's Great Red Spot, was likely a storm in the clouds of Neptune's atmosphere. When the planet was viewed again in 1994 through the Hubble Space Telescope, the spot was gone. A new dark spot has since appeared in the northern hemisphere.



Planet	Average Distance from Sun (AU)	Radius (km)	Mass (relative to Earth)	Average Surface Temperature (°C)	Period of Rotation (relative to 1 Earth day)	Period of Revolution (relative to 1 Earth year)
Jupiter	5.27	71 492	317.8	–150	0.41	11.9
Saturn	9.54	60 268	95.2	–170	0.45	29.5
Uranus	19.19	25 559	14.5	–215	0.72	84.0
Neptune	30.06	24 764	17.1	–215	0.67	165.0

11-2A Terrestrial and Jovian Planets

Think About It

In this activity, you will investigate the differences between terrestrial and Jovian planets. The terrestrial planets are Mercury, Venus, Earth, and Mars. The Jovian planets are Jupiter, Saturn, Uranus, and Neptune.

Criteria	Terrestrial Planets (Inner)	Jovian Planets (Outer)
Size		
Motion		
Composition		
Distance from Sun		
Temperature		
Density		

What To Do

Use the information on pages 400 and 401 of your textbook to compare the terrestrial and the Jovian planets. Create a table like the one shown with the following categories: size, speed of motion around the Sun, composition (what are the planets primarily made of), distance from the Sun, temperature, and density.

Other Solar System Bodies

Keeping the eight planets company in our solar system are numerous other small bodies.

Moons

All the planets except Mercury and Venus have one or more orbiting companions. Astronomers call these "satellites." (These satellites are not the same as the human-made satellites that are sent into orbit around Earth to provide communication services, mapping, and surveillance.) Our satellite has been named the Moon, and so we usually refer to other planets' orbiting companions as **moons** too. So far, more than 165 moons have been detected in the solar system.

Earth's Moon most likely formed early in Earth's life when Earth was still a hot, molten planet. A body the size of Mars likely collided with Earth, sending debris into space in orbit around what was left of Earth. Gravitational forces brought much of the debris back together to form Earth while other debris formed the Moon (Figure 11.11).

Figure 11.11 The Moon is thought to have formed as a result of a great collision between Earth and another solar system body the size of Mars.

Dwarf planets

A **dwarf planet** is a celestial body orbiting the Sun that is generally smaller than a planet but massive enough for its own gravity to give it a round shape (Figure 11.12). Dwarf planets do not have enough mass, and therefore enough gravity, to clear their orbits of small debris left over from the formation of the solar system. Pluto, once considered the ninth planet, is the most famous dwarf planet but it is not the largest. Eris, discovered in 2003, is larger than Pluto. Haumea and Makemake [pronounced ma-ki ma-ki] are two other dwarf planets that orbit the Sun with Pluto and Eris outside of Neptune's orbit. Ceres is also a dwarf planet, and orbits in the asteroid belt between Mars and Jupiter.

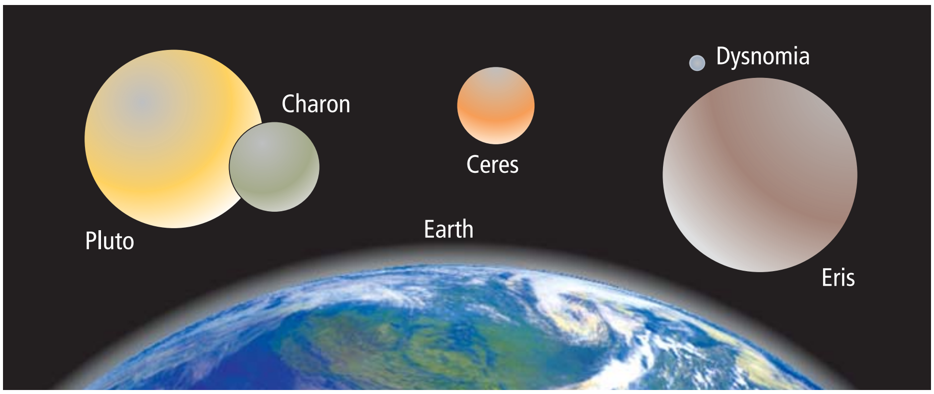


Figure 11.12 A comparison of three dwarf planets and Earth. Note that both Pluto and Eris have moons. Haumea and Makemake are larger than Ceres.

Asteroids

Asteroids are small bodies that are believed to be leftover remains of the formation of the solar system. Most asteroids orbit the Sun in a band between Mars and Jupiter (Figure 11.13). Asteroids range from the size of sand grains up to about 1000 km across—about the diameter of Ceres. Although some may be spherical, many have irregular shapes.

Some asteroids exist inside of Mars' orbit and pose a threat to Earth. The orbits of Near Earth Asteroids (NEAs) sometimes cross the orbit of Earth. The impact of an asteroid of 1 km in diameter on Earth would cause devastation and threaten human existence by hurling material up into the atmosphere, blocking out sunlight for months, and threatening our food supply.

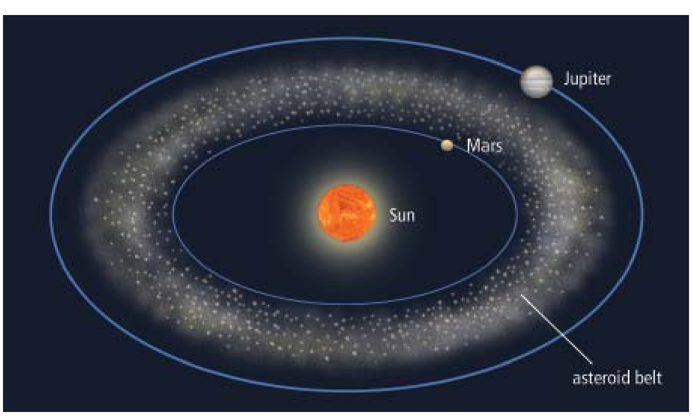


Figure 11.13 Thousands of asteroids orbit in the asteroid belt.

internet connect

The giant impact theory of the Moon's origin explains much of the evidence we can observe, but there have been four other popular theories about its formation. To find out more about these theories, visit **www.discoveringscience9.ca**.

Word Connect

"Lunar" comes from Luna, the Roman goddess of the Moon. Lunar describes anything relating to the Moon. Folklore suggests that some people act in crazy ways whenever there is a full moon, which is where the word "lunatic" comes from.

Explore More

The Planet Pluto was demoted to dwarf planet status by astronomers in 2006. Find out the reasons for this demotion. From your research, determine if you agree with this decision and explain why. Begin your research at **www.discoveringscience9.ca**.

Did You Know?

Astronomers once thought that our solar system was the only one that existed. Today, we know that more than 300 planets have been discovered orbiting nearby stars.

Explore More

To remember the order of the planets out from the Sun, many simple phrases have been developed. For example, "My Very Excellent Mother Just Made Us Nachos." Can you come up with other phrases for the planets? Can you include the names of the dwarf planets in your phrase? Remember, Ceres is between Mars and Jupiter. Pluto and Eris are in the Kuiper Belt outside of Neptune's orbit.

Trans-Neptunian objects

Objects that circle the Sun beyond the orbit of Neptune are called trans-Neptunian objects. The Kuiper Belt is a flat disk of millions of small bodies orbiting the Sun. Like the asteroid belt, the **Kuiper Belt** is thought to be composed of fragments of material left over from the formation of the solar system (similar to the collection of dust around the edges of a swept patio).

Orbiting in this cloud of material are small bodies similar in composition and size to the dwarf planet Pluto. The largest Kuiper Belt object is the dwarf planet Eris. It is almost 400 km wider than Pluto and, like Pluto, has its own moon. In 2006, the International Astronomical Union promoted Eris to dwarf planet status. At the same time, Pluto was demoted to a dwarf planet as well. That demotion ended Pluto's 76-year history as the solar system's ninth planet.

Astronomers currently suggest that there are at least 23 objects orbiting in the Kuiper Belt that may be considered dwarf planets. As technology improves, more objects will undoubtedly be discovered.

At the farthest reach of the Sun's gravitational influence lies a spherical cloud of small icy fragments of debris called the **Oort Cloud**. Along with the Kuiper Belt, the Oort Cloud is thought to be a source of comets. It is between 50 000 and 100 000 AU away from the Sun. (Remember, Earth is 1 AU away from the Sun.) The Oort Cloud is roughly one quarter of the distance to the next nearest star to us, Proxima Centauri.

Comets

Comets are often referred to as "dirty snowballs," composed of ice, rock, and gas. Information collected by space probes, however, has shown that comets consist of far more rocky material than originally suspected. They hurtle through space, originating from the Kuiper Belt and the Oort Cloud. Every once in a while they are bumped into the inner solar system. They travel in a long, elliptical orbit around the Sun, which can be modified through the gravitational attraction of the planets, primarily Jupiter. They may even be placed on a collision course with a planet or the Sun. In 1992, Comet Shoemaker-Levy 9 passed by Jupiter and was torn apart by its gravity. Over a one-week period, the 21 mini-comets impacted on Jupiter and the resulting scars were visible from Earth (Figure 11.14).

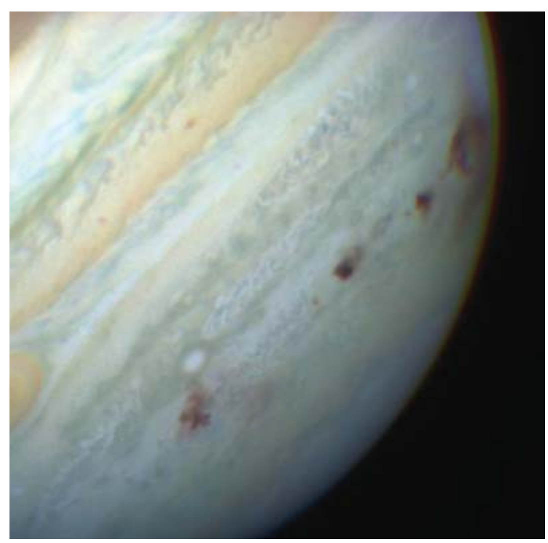


Figure 11.14 Dark markings in Jupiter's clouds mark the impact points from remnants of Comet Shoemaker-Levy 9.

The most spectacular feature of a comet is its long dust tail, which can stretch for millions of kilometres. Once a comet feels the effect of sunlight, it begins to melt, releasing its trail of gas and dust streaming away from the Sun (Figure 11.15).

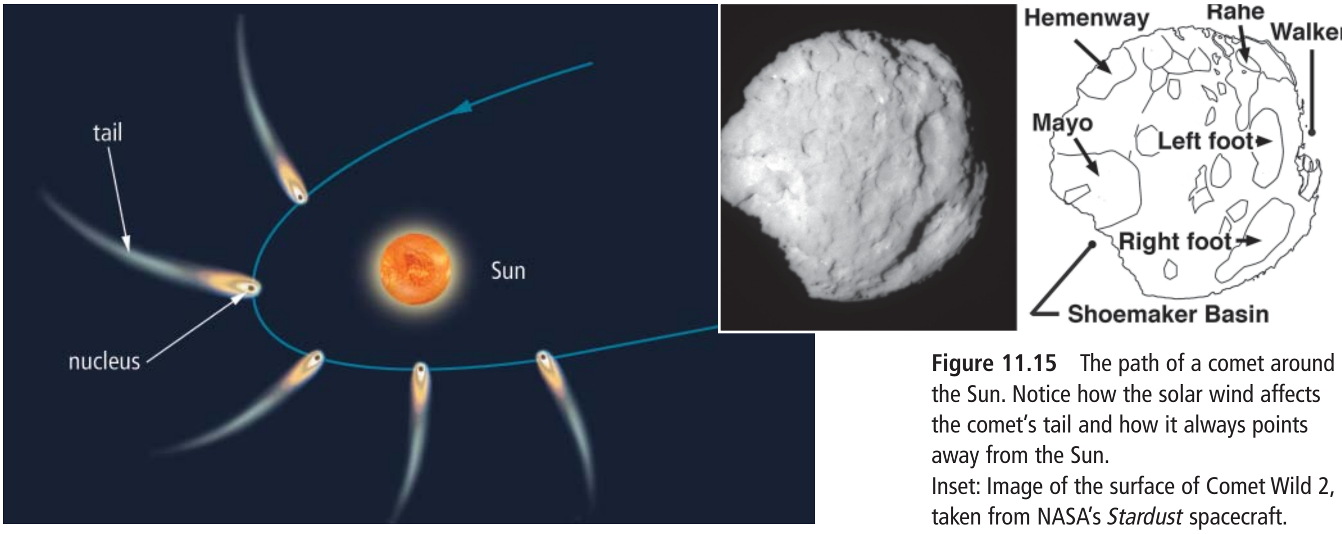


Figure 11.15 The path of a comet around the Sun. Notice how the solar wind affects the comet's tail and how it always points away from the Sun.
Inset: Image of the surface of Comet Wild 2, taken from NASA's *Stardust* spacecraft.

The *Deep Impact* space probe flew past Comet Temple 1 in 2006. It released a probe which crashed into the comet's nucleus, releasing a plume of dust and ice. *Deep Impact* took photographs and used scientific instruments to analyze the plume as it flew by the comet (Figure 11.16).

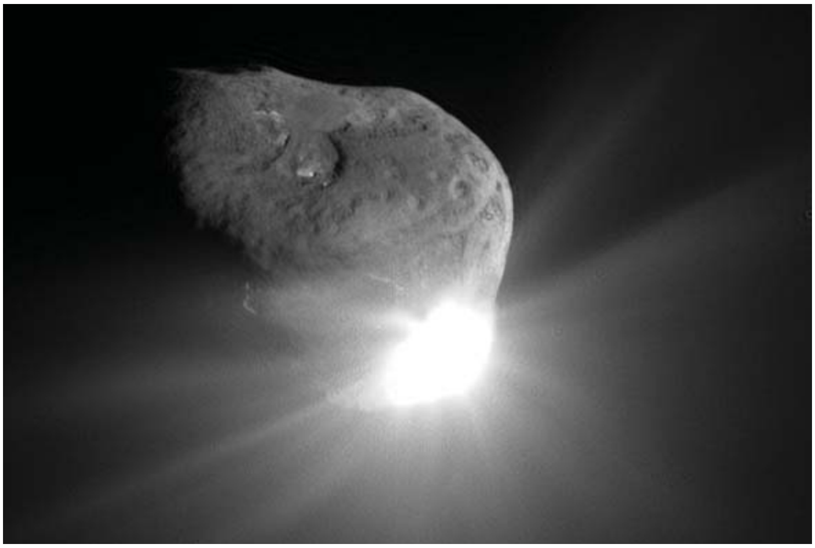
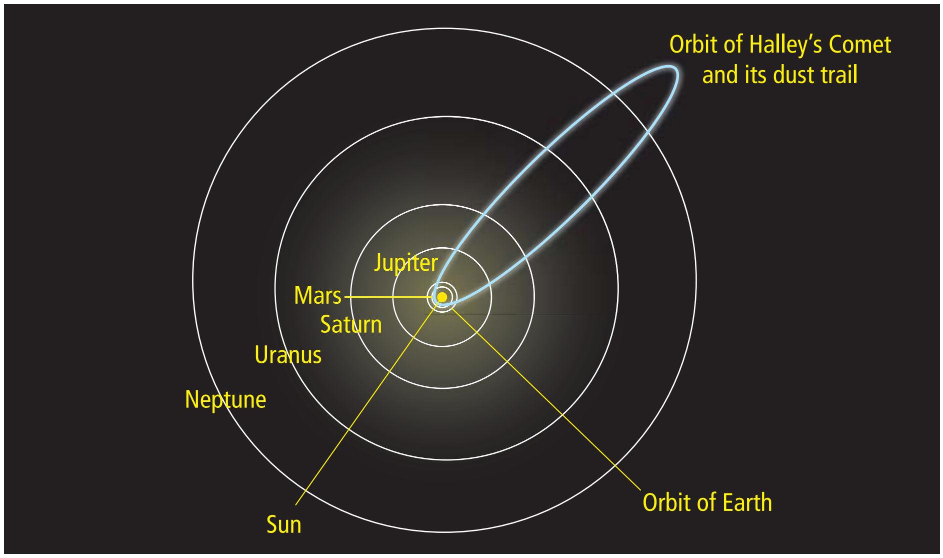


Figure 11.16 The *Deep Impact* Spacecraft took pictures of a probe it fired at the nucleus of Comet Temple 1 in 2006.

Halley's Comet (rhymes with valley), as shown in Figure 11.17, is the most famous comet because it is bright enough to see with the naked eye and appears more frequently than other comets. In the 1700s, British astronomer Edmond Halley was searching records and realized that a bright comet was visible every 76 years or so. Originally thought to be a different comet, it was Halley who figured out that this comet was the same as before. He predicted its return in 1758. The last time it was visible was 1986. It will return in 2061 (Figure 11.18 on the next page).

Figure 11.17 Halley's Comet

Figure 11.18 Halley's Comet is in an elliptical orbit that takes it out beyond Neptune's orbit and in past Earth orbit.



Suggested Activity

Think About It 11-2C on page 409

Word Connect

The word "comet" comes from the Greek word *kometes* meaning long-haired star.

Meteors

Meteoroids are pieces of rock floating through space. They can be chunks of asteroids or planets broken by collisions with other asteroids or other bodies, or they may even be debris left over from the formation of the solar system. What some people call "shooting stars" are really **meteors**, which are meteoroids that burn up as they enter Earth's atmosphere at high speed (Figure 11.19). Very occasionally, meteors are large enough to survive passing through the atmosphere, and they reach Earth's surface. These chunks of rock are called **meteorites**. About once every 100 million years or so, extremely large meteorites hit Earth (Figures 11.20 and 11.21 on the next page).

Did You Know?

When Comet Halley visited the inner solar system in 1910, it was determined that the tail of the comet contained cyanide and that Earth would pass through it. Gas masks and "Comet Pills" were sold to protect people from the poisonous cyanide, although scientists assured people that the cyanide was dilute and there was no chance anyone would be harmed.

Figure 11.19 This meteor shower is made up of particles the size of sand grains that burn up as they pass through Earth's atmosphere.

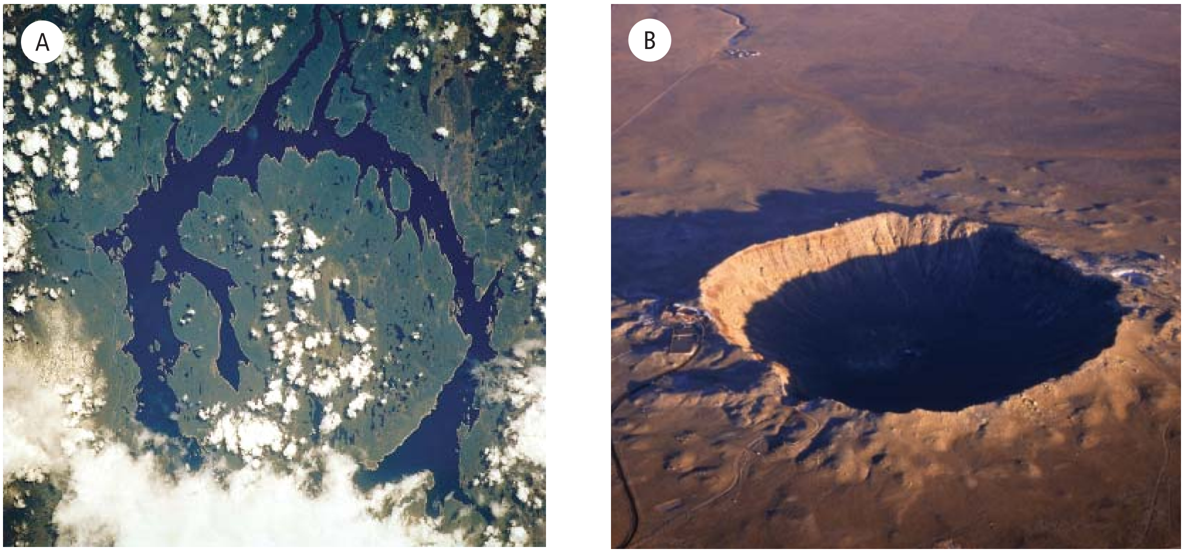


Figure 11.20 The Manicouagan crater in Quebec (A) shows what can happen when a meteorite reaches Earth's surface. The Manicouagan crater is 70 km wide and is extremely old. Compare it to a more recent impact: The Barringer meteor crater in Arizona (B) was formed only 50 000 years ago when a 50 m diameter meteor hit Earth.

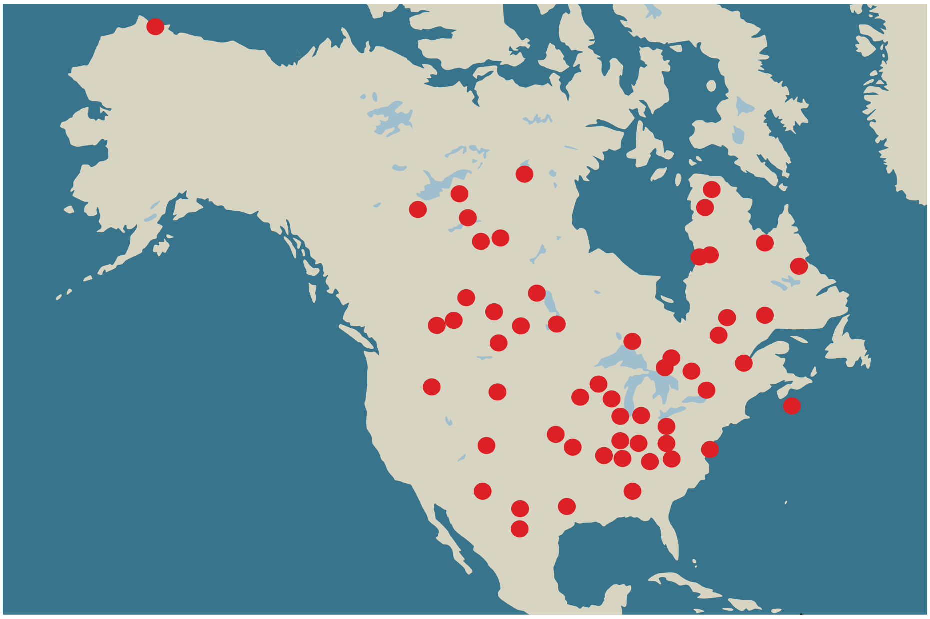


Figure 11.21 This map shows sites in North America where meteorites are known to have landed.

Reading Check

1. What are the three conditions that must be met to classify a celestial body as a planet?
2. Name two planets that do not have moons.
3. How many planets in the solar system have liquid water, ice, and clouds?
4. Where are most asteroids found?
5. How are meteors formed?

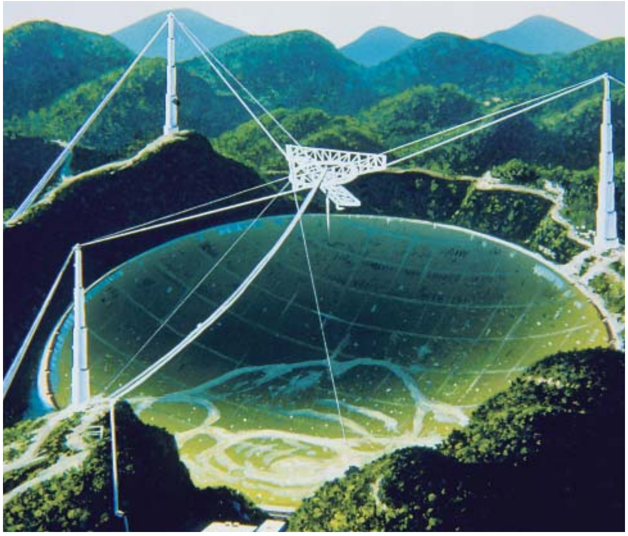
Wild, Weird, Wonderful

www Science

Is Anybody Out There?

Life on Earth seems to exist everywhere. Scientists are constantly discovering new species of organisms on this planet in places no one had previously imagined anything could live. We now know there is life beneath the frozen land mass of Antarctica, inside sulphur deposits several kilometres underground, and even in the superheated water in the cracks of rock surrounding volcanic magma chambers.

The ingredients that create organic molecules on Earth have recently been found in gas clouds in space. Discovering this has encouraged many people to search for extraterrestrial life—that is, life beyond Earth. Astrobiologists study the possibility that extraterrestrial life exists. They suggest that if life can be found in the most hostile environments on Earth, there is a good chance it can be found in environments on other planets, inside and outside of our solar system.



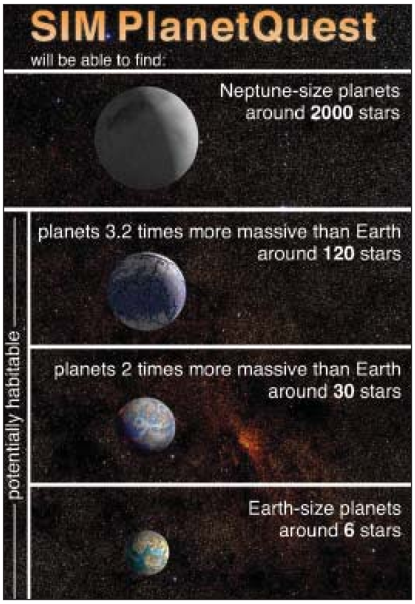
The Arecibo Observatory radio telescope is almost as wide as three football fields and can "listen" for signals from space.

Italian physicist Enrico Fermi proposed that if intelligent life exists in the universe, we should be able to detect it. The Search for Extraterrestrial Intelligence, or SETI, is an organization dedicated to looking for evidence of life in the universe. Several associations around the world are involved in the search.

Recall that many objects in space produce electromagnetic radiation of various forms, including radio waves, gamma rays, and X rays. Observers are therefore looking for any type of signal not produced by a source or for a reason they can otherwise explain. Giant radio telescopes, such as the Arecibo Observatory in Puerto Rico (shown at left), scan the sky in search of signals that stand out from the background radiation of the universe. To date, there have been a number of interesting signals but no actual detections.

Evidence of life can come in more forms than just radio signals. All the life forms on Earth are made from carbon-based molecules. Water provides an excellent environment in which organisms with a carbon-based chemistry can grow. For this reason, astronomers are searching for any celestial body that contains water. In addition, they are interested in studying the atmosphere of planets beyond Earth to look for telltale signs of life. Carbon dioxide is a product of cellular respiration, and oxygen is a product of photosynthesis. If these gases are found in the atmosphere of a planet, it may indicate the presence of some form of life.

Astronomers have already detected more than 300 planets revolving around stars thousands of trillions of kilometres away from us. Although most of these planets are very massive, a few have masses similar to Earth's.



An artist's impression of the type of other Earth-like planets astronomers are searching for.

11-2B Making Craters in the Classroom

Find Out ACTIVITY

Some meteorites have enough energy and mass that when they hit Earth, they make a large circular indention in the surface called an impact crater. Impact craters can take on various shapes based on the meteorites' size and the speed with which they hit Earth. In this activity, you will learn more about meteorites and impact craters.

Materials

- newspaper
- about 3–5 small round rocks and/or balls of different sizes, about 1–3 cm in diameter
- plastic tub
- flour
- cocoa powder
- flour sifter or salt shaker
- metre stick or measuring tape

What to Do

1. Spread the newspaper on the floor and place the plastic tub in the centre.
2. Fill the tub with flour so that it is about 3 to 5 cm deep. Do not press the flour down.
3. Using a flour sifter or salt shaker, sprinkle an even layer of cocoa powder over the flour.
4. Using the metre stick, measure a height from which to drop the rocks.
5. Drop the first rock into the pan from the height you chose. Carefully remove the rock from the flour. Observe the crater it made. (The cocoa powder will help you see how the surface moved.)
6. Without repairing the surface, drop another rock into the flour. Drop it from the same height as you dropped the previous rock (but drop it away from the first crater). Compare this rock's crater with that of the first rock.
7. Continue dropping the rest of your rocks at the same height using the same flour surface. Drop them so that they each make their own separate crater that does not overlap any other crater. Observe and compare each of the craters.
8. Repair the surface of the flour by smoothing it gently and shaking more cocoa powder on top. Choose one rock and drop it from three different heights to create three separate craters. Compare the craters you created.
9. Repair the surface of the flour again. Choose one rock and toss it gently into the flour from the same height, but from three different angles to create three different craters. Compare the craters you created.

What Did You Find Out?

1. What effect did the size of the meteorite have on the size of the crater?
2. What effect did changing the height from which the meteorite was dropped have on the size of the crater?
3. What effect does the impact have on material deeper in the surface?
4. How might explorers of this planet use craters to their advantage?
5. What happened when you tossed the meteors at a slight angle?

11-2C Comet Orbits

Think About It

In this activity, you will investigate where a well known comet came from, the shape and period of its orbit, and why it is easier to view during some pass-bys than others. Some common comets are: Hyakutake [pronounced Ya-koo-tah-kay], Hale-Bopp, Shoemaker-Levy 9, and Halley's Comet.

What To Do

1. Research information on the three types of comet orbits, starting at **www.discoveringscience9.ca**. Do all three orbits bring the comet back to the Sun?
2. Some comets have been easier to see than others. Compare the comets Hyakutake, Hale-Bopp, Shoemaker-Levy 9, and Halley's Comet. What affects the visibility of a comet?
3. What effect can the planets have on the orbit of a comet?

11-2D Nighttime Activities for the Astroscan—Observing Planets

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Identifying planets
- Recording

Safety

- Always perform your observations at night with adult supervision.
- Dress appropriately for the weather.

Materials

- Astroscan telescope
- star chart showing the night sky and positions of planet(s)
- planet-drawing chart
- clipboard
- flashlight (with red filter)
- pencil

Hint: Planets are usually the brightest objects in that part of the sky. They do not "twinkle" like stars so look for the brightest object that does not flicker or twinkle much. Planets appear much larger than stars and their appearance is less affected by distortion by Earth's atmosphere.

In this activity, you will use the Astroscan telescope to observe the planets visible in the night sky at this time of year. During any time of the year at least one of Venus, Mars, Jupiter, or Saturn should be easily seen in the night sky. Sometimes Mercury and Uranus are visible with the Astroscan telescope, but light pollution near populated areas often makes these planets difficult or impossible to see.

Question

What observations about planets can you make by observing with a telescope?

Procedure

1. Your teacher will provide you with a star chart for this month. It will show the planets that are visible in the night sky right now.
2. Find a location where there is a clear view of the southern part of the sky and set up the Astroscan telescope on its stand.
3. Put the 28 mm eyepiece in the telescope.
4. Look at the star chart and find out which of Venus, Mars, Jupiter, or Saturn can be seen early in the night at this time of year.
5. On the star chart, find a constellation nearby the planet that you can use as a guide. Then find that constellation in the sky and locate the position of the planet that you saw on the chart.
6. Set up the telescope so that it is pointing directly at the planet.
7. Use the planet-drawing chart to draw an image of the planet with any details you can see, even briefly. (Keep an eye out for moons close to the planet!)
8. Use a higher power eyepiece (a lower number) on the telescope and try to add more detail to your drawing.
9. Repeat the process for any other planets that you can see.

Analyze

1. Which planets appear brighter than the others? Why?
2. Which planets did you see in the telescope?
3. Using your drawing and what you know about that planet, describe what you may have observed.
4. Describe any details you saw in your telescope that are also shown in the pictures of the planet in your textbook.

Conclude and Apply

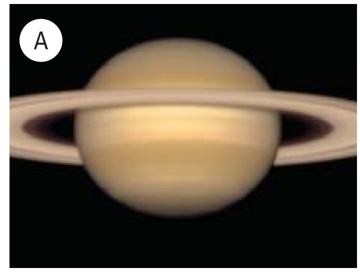
1. What observations could you make with the telescope that you were not able to make with the unaided eye?
2. In what ways did your observations confirm what you expected to see?
3. What did you see that you were not expecting to see?
4. How could a telescope help us learn about celestial bodies?

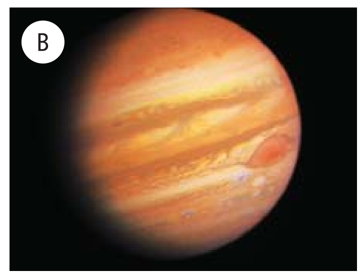
Checking Concepts

1. What types of information were uncrewed space probes able to confirm about the various planets they were sent to?
2. Which planet
   (a) has the shortest day?
   (b) is called the red planet?
   (c) has an atmosphere almost completely composed of carbon dioxide?
   (d) rotates flipped on its side?
   (e) has an extreme temperate range of 400°C to 183°C?
3. What do we believe occurred to form Earth's Moon?
4. (a) What is a dwarf planet?
   (b) Name five dwarf planets.
5. What does NEAs stand for?
6. Where is the Kuiper Belt found?
7. (a) Describe the composition of a comet.
   (b) How does the tail of a comet form?
8. What is a "shooting star"?

Understanding Key Ideas

9. An astronomical unit (AU) is the average distance between Earth and the Sun. Explain why the distances between bodies in the solar system are measured in astronomical units.
10. How did John Winthrop estimate the distance to the Sun?
11. Compare and contrast the following terms:
    (a) planet and solar system
    (b) comet and asteroid
    (c) trans-Neptunian objects and meteorite
12. Although asteroids orbit as planets do, why are asteroids not considered to be planets?
13. Explain why the frozen debris found in the Oort Cloud, more than 50 000 AU away from the Sun, is still considered part of the solar system.
14. The following photographs show parts of the most recognizable features of three planets in our solar system. Name the planets and their distinguishing features.





Pause and Reflect

An asteroid or comet striking a planet will create an impact crater or impact basin. Over 120 impact craters or impact basins have been discovered on Earth.

Chicxulub Basin in Mexico's Yucatan has a diameter of 300 km. It is believed that it was formed by an asteroid that struck Earth approximately 65 million years ago. Some scientists believe that this event is linked to the climate changes that led to the extinction of the dinosaurs. How could an asteroid striking Earth cause the extinction of a species?

11.3 The Exploration of Space

Human understanding of Earth and its place in the universe has evolved as technology has enabled us to see farther into space. Modern telescopes are placed on top of mountains or placed in Earth orbit. Probes and rovers are sent to explore other planets in our solar system. Canada has an active space program, taking part in missions both with crews and without crews.

Key Terms

geosynchronous orbit
optical telescope
probe
radio telescope
rover
satellite

Space technology is progressing at an amazing rate, enabling us and our instruments to travel farther and farther from Earth. In 1961, the first human went into space, followed since then by more than 400 others. In your parents' lifetime alone, people have walked on the Moon, a space-based laboratory has been established, and robotic probes have landed on Venus, Mars, an asteroid, and a moon of Saturn. Sophisticated telescopes have enabled us to see close-up images of every planet, and space-based telescopes have beamed back images that reveal the most distant regions of the universe (Figure 11.22).

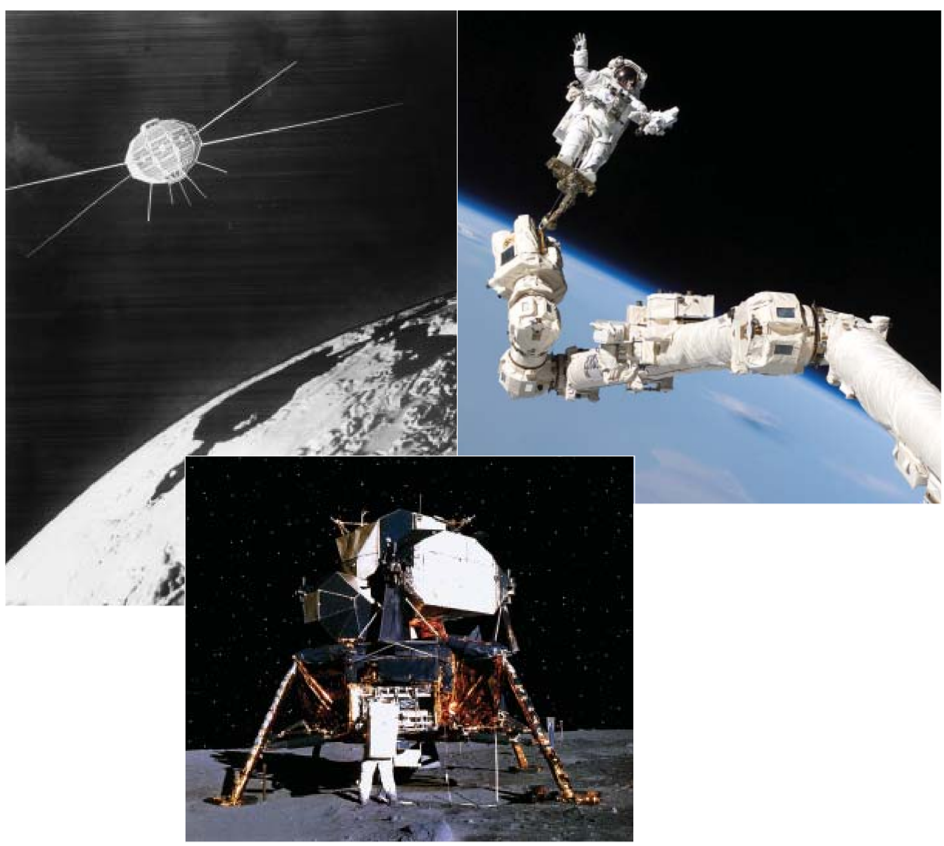


Figure 11.22 Canada has played a part in space exploration from the beginning. Canada was the third country to launch a satellite (*Alouette 1* in 1962), a Canadian company built the Canadarm and the legs of the lunar module that landed people on the Moon, and Canadian astronauts helped to construct the International Space Station and perform scientific research there.

Explore More

Prepare a biography on one of Canada's astronauts. Choose one of the following: Marc Garneau, Roberta Bondar, Chris Hadfield, Julie Payette, or another Canadian astronaut who you know of. Describe the astronaut's background and schooling, his or her experiences in space, and the reasons why he or she wanted to be an astronaut. Then, explain why you would or would not like to be an astronaut.

Technology of Space Travel

Breaking the hold of Earth's gravitational pull was the first challenge for scientists wishing to send telescopes, other instruments, or humans out into space. This task is done with rockets. Rocket technology has advanced dramatically since its humble beginnings in China in the first century C.E. The establishment of a space-based research facility on the International Space Station has taken space exploration to the next level.

Rockets

A rocket is a system used for transporting materials and astronauts into space. Much of the body of a rocket is filled with explosive fuels that combine to create thrust (Figure 11.23).

Thrust is the force that pushes against the rocket, causing it to move. A similar reaction occurs when you blow up a balloon and release it. The air escapes from the neck of the balloon and produces thrust, which forces the balloon to fly away. As fuel is used up, parts of the propulsion system are released from the rocket to make the body lighter.

Did You Know?

On its 3.8 billion km journey to Jupiter, the *Galileo* spacecraft had to adjust its direction from time to time with small bursts from its rockets. Doing this used only about 254 L of fuel for the whole trip, a fuel use of 15.6 million km/L.

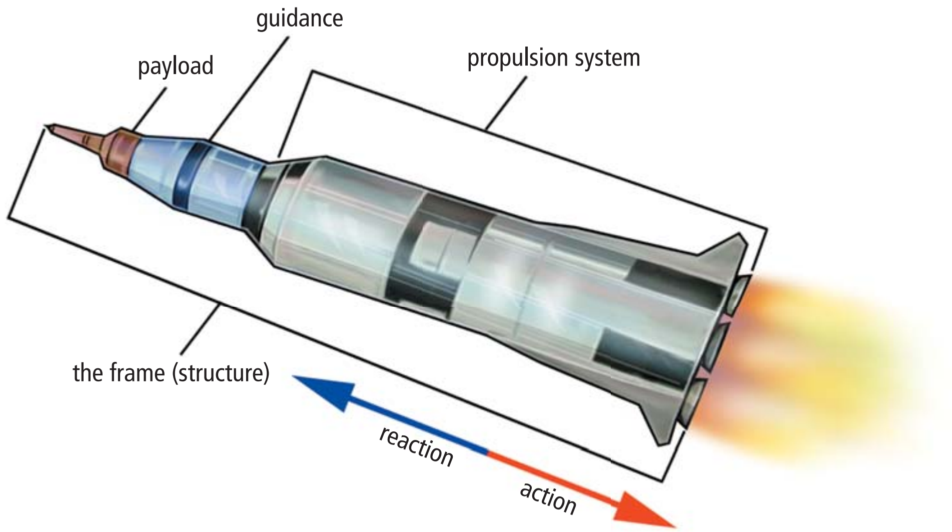


Figure 11.23 All rockets have four main systems: structural (the frame), payload, guidance, and propulsion. The payload is the cargo that the rocket carries. It could be astronauts, satellites, or other objects. The propulsion system produces thrust, the force needed to launch the rocket. The guidance controls the rocket's direction using computers.

11-3A Canada's Contributions to Space Exploration

Think About It

Sometimes we explore space by sending people into orbit, and sometimes we rely on data from rovers or space-based telescopes. When is each approach best?

What to Do

1. Research Canada's contributions to space exploration and the understanding of our solar system. List eight contributions that Canadians have made. Which ones involved humans travelling into space?
2. List the advantages and disadvantages of conducting space exploration by sending missions into space. Discuss your list with a classmate.
3. Write two or three paragraphs to answer this question: What kinds of space exploration require sending missions into space, and what kinds can be conducted from Earth?

Figure 11.24 A space shuttle, such as *Discovery* shown here, reaches its orbital speed of 27 200 km/h in just under 8 minutes.

Space shuttle program

Besides a rocket's payload, not much of the structure is saved or used again. Most of the material falls back to Earth, burning up during re-entry into the atmosphere or crashing into the ocean. For this reason, space shuttles were designed to be reusable spacecraft. Each shuttle is rocketed into space, completes its mission, and returns to Earth, gliding in on a runway like a regular airplane (Figure 11.24). The only discarded material is the large, orange external fuel tank.

In addition to launching and retrieving satellites, the shuttle is used as a means of delivering astronauts, supplies, and equipment to the International Space Station.

Suggested Activity

Core Lab Conduct an Investigation 11-3B on page 422

International Space Station

Since construction began in 1998, the International Space Station has been built piece by piece from components delivered by the space shuttle and from conventional rockets from Russia. Sixteen countries, including Canada, are involved in this space-based laboratory, which orbits about 350 km above Earth. Travelling at more than 27 000 km/h, the space station circles Earth in about 90 minutes. The onboard crew members conduct numerous experiments in the microgravity environment (Figure 11.25). Microgravity is the condition of weightlessness experienced by all objects, including spacecraft and humans, in space. It is very weak gravity, less than one millionth the effect on Earth. Scientists at the Canadian Space Agency are known around the world for their work in microgravity research. The lifetime of the International Space Station is expected to be about 30 years.

Figure 11.25 Crew in the International Space Station carry out a wide range of experiments, such as testing new materials and studying the long-term effects of space travel on humans.

Space Travel

The first stages of space travel involved launching uncrewed probes. Animals were then sent up to test the living conditions required for space travel. The next phase involved sending up humans. From there, the Moon became the focus of attention. In 1969, the U.S. landed the first people on the Moon: Neil Armstrong and Edwin "Buzz" Aldrin (Figure 11.26).

As countries realized how expensive space exploration was, they started working together. The International Space Station is an excellent example of a truly international mission. Numerous partnerships between private business and governments are now also working on space projects.

Figure 11.26 The first landing of humans on the Moon, 1969

Canadian contributions to space exploration

One of the largest successes in NASA's space program has been the Canadian-designed and -built robotic arms. The first "Canadarm" was used to retrieve and launch many satellites and to provide a stable platform for astronauts going about their tasks in space.

Canadarm 2, a mobile remote manipulator system designed for the International Space Station, does everything that Canadarm 1 did, but it is larger and able to move by itself (Figure 11.27). Moving like a caterpillar, the system can travel to nearly every part of the space station's exterior. The newest development is the robotic manipulator officially named Dextre (for "dexterous"), a two-armed robot that attaches to the end of Canadarm 2. It can perform tasks that previously required astronauts to work outside the safety of the space station.

Explore More

Find out more about Dextre, the Canadian Space Agency's "Special Purpose Dexterous Manipulator." Start by going to **www.discoveringscience9.ca**.

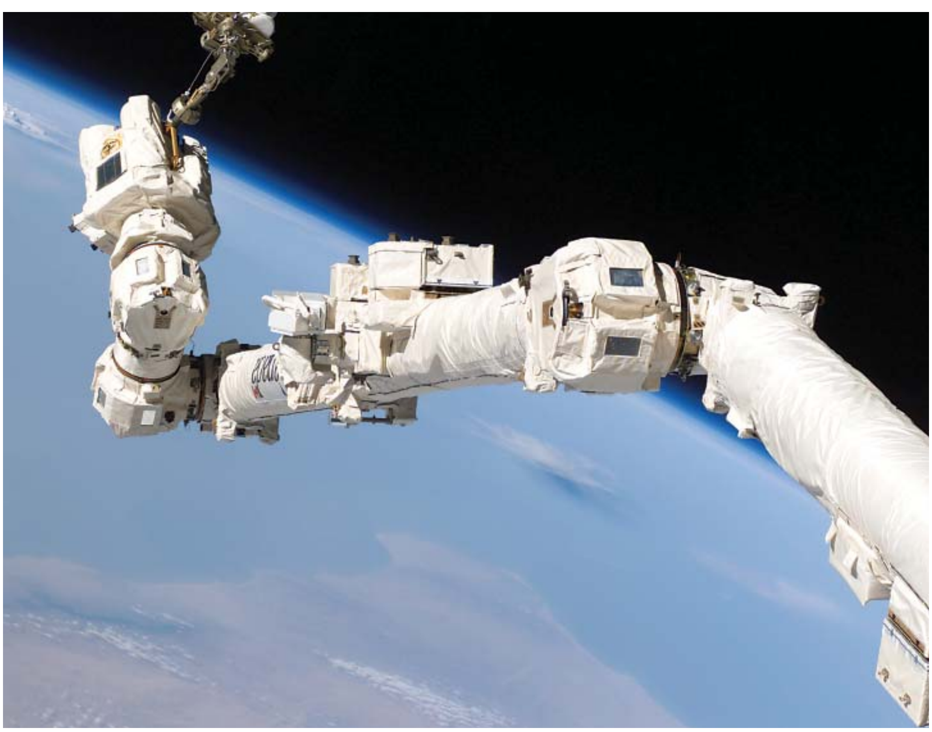


Figure 11.27 Canadarm 2 is used to move large payloads, dock the shuttle, and assist astronauts with repair and assembly duties.

Space Suits

Figure 11.28 An astronaut works on the Moon in a space suit. The backpack supplies oxygen, has a cooling system, and provides radio communication.

When astronauts step outside of their spacecraft in Earth orbit or on the Moon, they need to wear a spacesuit (Figure 11.28). If astronauts were exposed to the vacuum of space, they would quickly perish. A space suit acts as a small spaceship, providing oxygen to breathe. It contains a communications system, allowing astronauts to talk to each other and to people on Earth; a cooling system to keep the astronauts from overheating; and a system to simulate the air pressure on Earth's surface.

internet connect

Many different technologies are involved in designing and improving the components of space suits. To learn more about the features of current space suits, visit **www.discoveringscience9.ca**.

Reading Check

1. What creates the thrust of a rocket?
2. What is the purpose of the payload section of a rocket?
3. Define the term "microgravity."
4. What is Canadarm 2 and what can it do?

Orbiting Satellites

Artificial **satellites** are electronic devices put in orbit around Earth to relay information (Figure 11.29). "Satellite" means any body that orbits around another body in space. Our Moon orbiting Earth, for example, is Earth's natural satellite. It is common when talking about space technology to refer to artificial satellites simply as satellites.

Figure 11.29 Satellites are a very important part of your everyday life. When you decide what clothes to wear based on a weather report, or when you watch television, phone a friend, or check out a website, satellites are likely playing some role.

When a satellite is in Earth orbit, it is literally falling around Earth. Look at Figure 11.30. If you stand on a mountain and hit a baseball, the baseball falls to Earth. The harder you hit it, the faster it travels, and the farther it travels before it falls. If you could hit the ball hard enough, it would continue to fall, but it would keep missing Earth. If it was hit outside Earth's atmosphere, it would not be slowed down by friction with the air, would continue to travel at the same speed and fall at the same rate, and would continue to orbit Earth. The speed at which you would have to hit the ball is about 8 km/s.

Figure 11.30 To hit a baseball into orbit, you have to hit it above the Earth's atmosphere at a speed of 8 km/s.

Satellites in low Earth orbit—say 300 to 500 km—travel once around Earth every 90 minutes. The farther out a satellite is placed, the longer it takes to make one orbit. A satellite placed above the equator at a distance of 36 000 km would take 24 hours to make one orbit. Since the Earth also rotates once in 24 hours, the satellite would appear to sit above the same place on Earth. Communication satellites (television, Internet) are placed in this orbit, called a **geosynchronous orbit**.

Satellites are also used for many purposes besides providing communication services. Through remote sensing, for example, satellites are used to monitor forest fires, track migrating salmon, calculate the depth of oceans, and measure ground movement in an effort to predict earthquakes and volcanic eruptions. Remote sensing is a technique of collecting information about Earth from satellites, aerial photographs, or other means by "sensing" the planet from high above it (Figure 11.31).

Figure 11.31 One of the Canadian Space Agency's first remote sensing satellites was *RADARSAT 1*. *RADARSAT 2*, shown to the left, is the newer version, and is used for geological mapping, forest mapping, iceberg detection, and marine surveillance.

Zero gravity

In the International Space Station (ISS), astronauts appear to be floating. We call this "zero gravity," although this term is incorrect. A better term is "freefall." The ISS is in orbit around Earth, so it is falling around Earth. The gravitational pull of Earth is keeping the ISS in orbit. Imagine the gravity to be a string tied to the ISS. If there was no gravity, the string would be cut and the ISS would travel off into deep space.

Probes

A space vehicle sent to other celestial bodies is called a **probe**. Probes are designed to travel millions of kilometres, carrying scientific instruments to analyze distant objects in space. They may fly past, orbit, or land on a planet, moon, comet, or asteroid and send back information about its atmosphere and surface features. Every planet in our solar system has been visited by a probe. The *New Horizons* probe, launched in 2006, is destined for Pluto. It expected to reach that dwarf planet in 2015.

Space probes do not need a crew, which eliminates the risk to human life. They also do not need to return to Earth. From the late 1960s to early 1980s, for example, the Soviet Union landed several *Venera* probes on Venus. The planet's sulphuric acid clouds, 467°C temperature, and extreme surface pressure meant that most of the probes lasted less than half an hour before communication was lost. Despite that, the data and images that the probes were able to transmit have been invaluable.

Figure 11.32 Jupiter and one of its moons as viewed by *Voyager 2*

Two of the most successful American space probes have been *Voyager 1* and *Voyager 2*. Launched in the late 1970s, the two interplanetary explorers were the first to fly past the gas giants and the moons of the outer solar system (Figure 11.32). Today the probes continue to send back data from the farthest reaches of our solar system.

Rovers

Sending human explorers on long space journeys to distant, dangerous planets is not a practical idea. One reason is the risk to human life. Another reason is the enormous cost. Robotic space explorers offer a better option. These robotic devices, or **rovers** as they are commonly known, can be programmed to carry out tests that humans would otherwise make. Rovers are small, sophisticated, movable probes designed to land on a planet, explore and test the surface, and send the information back to Earth. Because of the length of time it can take for radio signals to travel between Earth and a remote location, rovers must be programmed to solve many problems on their own, without help from scientists at mission control.

Robotic space rovers work all day long, pausing only at night to conserve their battery strength. They operate in hostile environments that can range from the freezing surface of Mars to the furnace-like surface of Venus. The work they do includes conducting experiments in geology, meteorology, and biology.

The latest rovers to explore another planet are twins called *Spirit* and *Opportunity*. Sent to Mars, these "robotic geologists" have been testing rock samples and looking for evidence of water since January 2004 (Figure 11.33). They continue to send data, long past their original three-month mission.

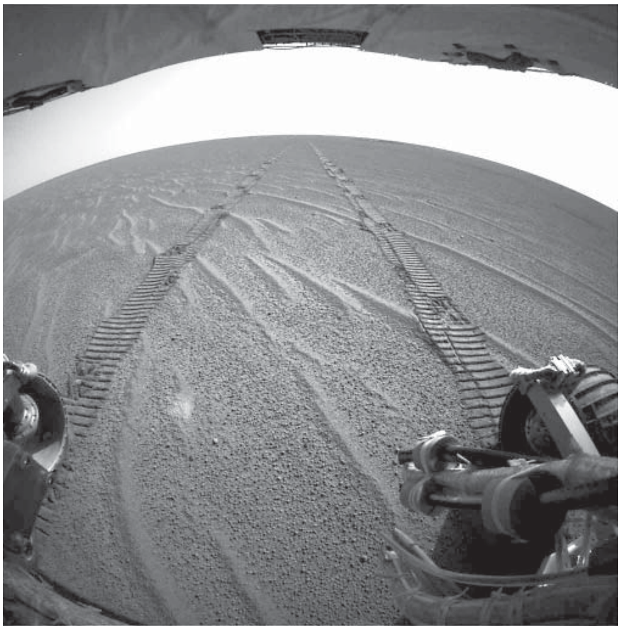


Figure 11.33 A camera on the Mars rover *Opportunity* looks back at its tracks as it explores the surface of Mars. The wide angle lens on the camera allows us to see close up, but distorts the shape of the planet.

Earth-based Observation Technology

The first telescope was invented by the Dutch eyeglass maker Hans Lippershey in 1608. Since then, many changes to its design have improved its light-collecting capabilities. There are two types of **optical telescopes**: refracting and reflecting.

Optical telescopes

Refracting optical telescopes use lenses to gather and focus light to provide a magnified view. Reflecting telescopes use a series of mirrors to collect light and project the image to an eyepiece lens for the viewer.

Earth-based telescopes, as sophisticated as they are, are affected by a number of conditions that can make observing difficult or impossible. These conditions include cloudy weather, air and light pollution, and distortion caused by heat and atmosphere.

Large observatories, which cost millions of dollars to build and run, are placed on top of mountains that are above most of the air, giving a clearer view and providing cloud-free skies (Figure 11.34).

Figure 11.34 The Canada-France-Hawaii Telescope is located on the 4200 m dormant volcano Mauna Kea in Hawaii.

Figure 11.35 To get an even better view, the Hubble Space Telescope was placed in Earth orbit by the space shuttle *Discovery* in 1990. With no air to spoil the view, Hubble has given us amazing views of far away objects in space, increasing our knowledge of the universe.

Radio telescopes

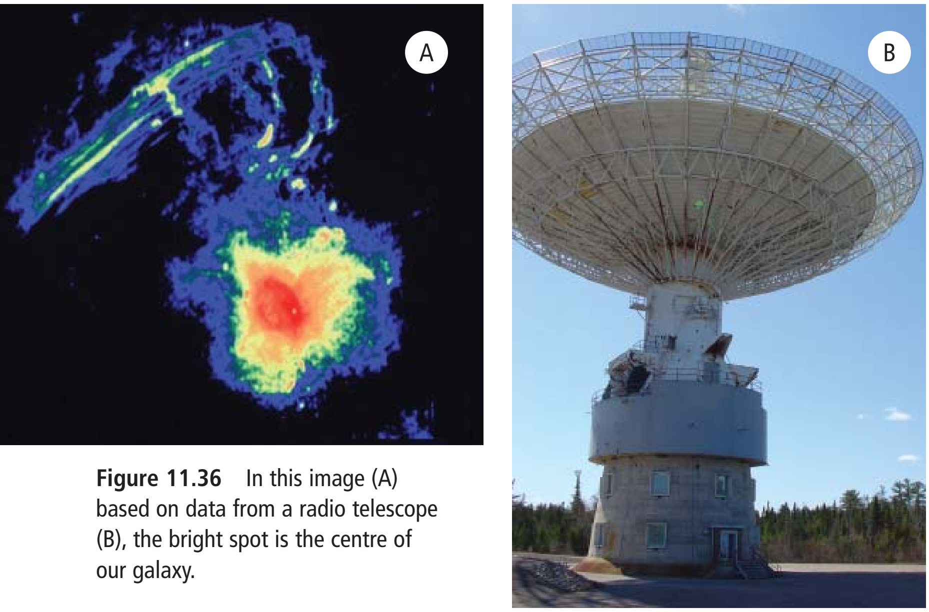


Figure 11.36 In this image (A) based on data from a radio telescope (B), the bright spot is the centre of our galaxy.

To collect wavelengths that are longer than those of light, **radio telescopes** are used. Radio telescopes are large receivers, similar to satellite dishes that you can often see attached to people's homes. Radio signals coming from a distant object are collected and focussed on a receiver. The radio signals are converted into electric impulses that are then interpreted as data. Radio telescopes reveal characteristics of celestial objects that could not be studied using optical telescopes (Figure 11.36).

Figure 11.37 The Very Large Array facility is used by astronomers from all over the world to study galaxies, black holes, planetary nebulae, and other areas of astronomy.

As with optical telescopes, radio telescopes can be joined electronically to produce the results of one very large telescope. The Very Large Array radio astronomy observatory, located in New Mexico, is made up of 27 antennas that are each 25 m across (Figure 11.37). The result simulates one giant radio telescope that would be 36 km wide.

Did You Know?

Building large telescopes can be difficult and expensive. Another strategy is to use two or more smaller telescopes to create the power of a single large one. Combining a series of telescopes to imitate the sensitivity of a single, larger telescope is called interferometry.

Reading Check

1. Define the term "artificial satellite."
2. Other than communication, list three ways that satellites help scientists.
3. Give two reasons why a probe would be sent to another planet before a human would.
4. Why are radio telescopes used?

Science Watch

Canada's Suitcase Satellite Searches for Other Earths

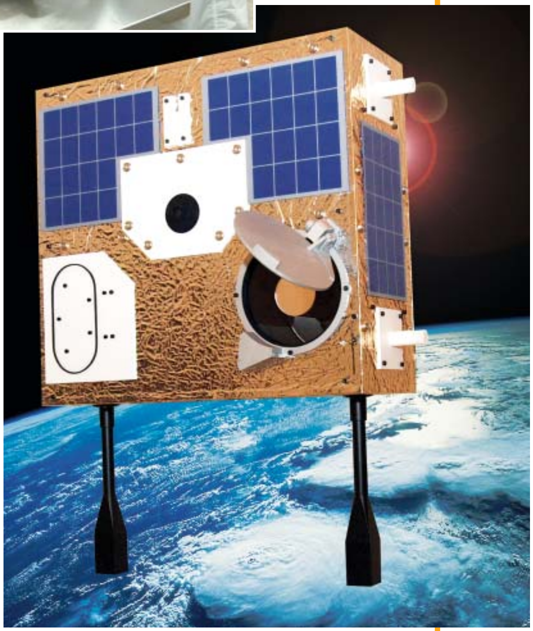
Searching for extra-solar planets (that is, planets that are not in our solar system) is extremely difficult. Unlike stars, planets do not give off their own light. They only reflect light from the star around which they orbit. Furthermore, the light that does reflect off them has to travel great distances in space before we can hope to detect it here on Earth. This challenge is where Canada's first space telescope comes in. The *MOST* (**M**icrovariability and **O**scillations of **St**ars) telescope monitors the slight variations in brightness of stars. When a planet orbiting a distant star passes between Earth and the star, the star's light dims very slightly. The change in brightness is similar to what might be detected if a mosquito flew in front of a 400 Hz streetlight viewed from a distance of 1000 km!

Affectionately called the "Humble Space Telescope," Canada's *MOST* satellite is only about the size of a suitcase. The satellite orbits Earth from pole to pole at an altitude (height above Earth) of 820 km. It takes about 100 minutes for *MOST* to circle the planet. This altitude allows the satellite to remain focussed on its target star. The *MOST* program hopes to detect and analyze light reflecting from planets orbiting nearby stars as well as determine ages and compositions of the oldest stars closest to our solar system.

MOST sends data to the University of British Columbia for interpretation. Astronomers hope that this information can lead to answers to questions such as: How does our Sun compare with other stars? How do the planets in our solar system compare with planets in other solar systems? and even, How were planets able to form at all?

The next few years promise to be exciting times for Canada's space telescope, filled with wonderful new discoveries about solar neighbourhoods close to our own.

Dr. Jaymie Matthews, principal investigator with the *MOST* project



Costing $\frac{1}{150}$ of the Hubble Space Telescope, Canada's *MOST* satellite has helped astronomers detect the presence of planets orbiting stars many light-years from our solar system.

Questions

1. Why is finding planets that orbit distant stars so difficult?
2. How does *MOST* detect planets?
3. State two of the questions that astronomers hope the *MOST* satellite will answer.

11-3B Designing a Space Station

Conduct an INVESTIGATION

SkillCheck

- Researching
- Planning
- Reporting

Inquiry Focus

In this investigation you will design a space station in orbit around Earth.

Question

How would you design a space station that is safe for people to live in, taking into account all the environmental effects of being in space (including solar radiation, solar storms, and temperature control, among others)?

Procedure

1. Working in groups, identify the major environmental factors that a space station needs to protect against.
2. Research to find technology that will help to protect people and equipment from the factors you identified.
3. Design components of a space station that use the technologies you identified in step 2 to keep people and equipment safe.
4. List the resources that will need to be present to allow astronauts to live and work on a space station.
5. Build a model, create a diagram, or plan and perform a skit to show how you will obtain and dispose of the resources and to explain how the protective elements of your space station work.

Analyze

1. What are the three most important environmental factors to plan for?
2. How did you design the station to keep the astronauts safe?
3. What roles will the astronauts need to perform on your space station?
4. Where will you get your food, air, and water?
5. Where will you get power?
6. What will you do if parts of the space station break down?
7. What will you do if you have to go outside to fix the station?

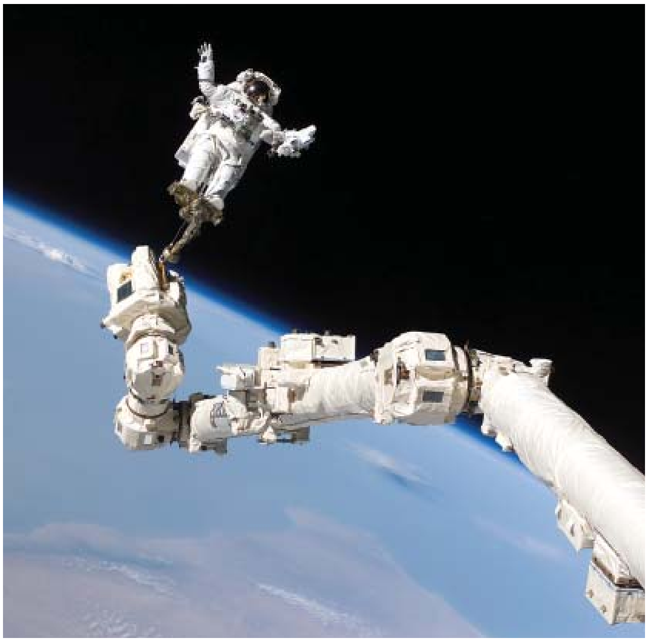
Conclude and Apply

1. Why might people with different skills and training be useful in designing a space station?
2. In what ways might it be useful to have people with different skills and training living together in a space station?
3. What would be important skills to have represented in the space station crew? Why?

Check Your Understanding

Checking Concepts

1. Name three contributions Canada has made to space exploration.
2. What is the main purpose of a rocket?
3. Why is the International Space Station referred to as "international"?
4. What are some of the advantages of Dextre?



5. State the difference between the following:
   (a) satellites and probes
   (b) optical telescopes and radio telescopes
6. Why are communication satellites placed in a geosynchronous orbit?
7. When referring to astronauts floating in their spacecraft, why is the term "freefall" a better term than "zero gravity"?
8. What is the main difference between a refracting optical telescope and a reflecting telescope?

Understanding Key Ideas

9. Describe a disadvantage of using a telescope positioned in space.
10. Match the systems of a rocket in column A with their description in column B.

A	B
Systems of Rocket	**Description**
(i) structural	(a) provides thrust to launch the rocket
(ii) payload	(b) controls the direction of the rocket
(iii) guidance	(c) frame for holding all the rocket systems
(iv) propulsion	(d) the material, including astronauts, carried by the rocket

11. What advantage is there to doing laboratory experiments on the International Space Station rather than doing the same experiments on Earth?
12. Why did the robotic space rovers that were sent to Mars have to be programmed to solve problems on their own rather than be totally controlled by scientists on Earth?
13. What are the main differences between Canadarm 1 and Canadarm 2?
14. What factors must be taken into consideration when designing a spacesuit?
15. Thirty-five different nations have sent their citizens into space. In your opinion, how should we determine who owns space?

Pause and Reflect

In this section, you have learned about the various opportunities awaiting adventurous space explorers. You have also learned that space travel has risks. If you were given a chance to be one of the first astronauts who was travelling to Mars, would you go or not? Write a short paragraph that explains what your decision would be and why you came to that decision.

Chapter Review

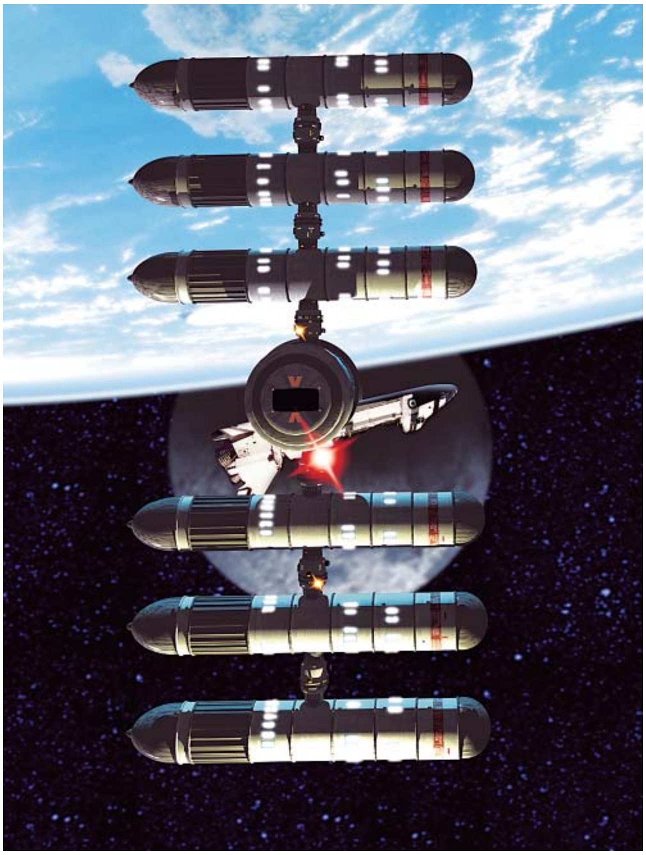
Checking Concepts

1. Give three features that could be used to describe the Sun.
2. Draw a labelled cross-section of the Sun's outer atmosphere. Label the chromosphere, photosphere, sunspots, and prominences.
3. How does the temperature of sunspots compare with temperatures in the rest of the photosphere?
4. What possible effects could a solar storm have on astronauts in space stations?
5. What name do astronomers give to the average distance between the Sun and Earth?
6. Why does a comet's tail always point away from the Sun?
7. Compare the environments found on Venus and Mars.
8. What causes "shooting stars"—the streaks of light that cross the night sky?
9. (a) What is the name of the force that causes a rocket to move?
   (b) How is this force applied to a rocket?
10. What advantages do orbiting telescopes, such as the Hubble Space Telescope, have over telescopes located on Earth?
11. Explain why it is less expensive to send robotic explorers to another planet than it is to send human astronauts.

Understanding Key Ideas

12. Compare the temperature conditions found at a solar prominence, the photosphere, and the chromosphere.
13. What risks do astronauts face during a solar storm?
14. Imagine that a new planet has been discovered between Saturn and Uranus. Describe the characteristics you would expect this planet to have.
15. Explain why landing a spacecraft on the surface of Neptune would prove to be very difficult.
16. Imagine you are in your spacesuit, holding a tin can of pop (the melting point of tin is 232°C, and the can is outside your spacesuit). Give as many reasons as you can for why you would not likely be able to open the can on Mercury or Venus.
17. Explain why the frozen debris found in the Oort Cloud, more than 50 000 AU away from the Sun, is still considered part of the solar system.
18. Scientists believe the Moon formed as a result of a Mars-sized object colliding with a young Earth. What do you think might have occurred if the object had been larger than Earth?

19. What is the relationship between a satellite's distance from Earth and the time it takes to make one orbit?
20. Describe an advantage of conducting experiments on the International Space Station.
21. Several *Venera* space probes were landed on Venus by the Soviet Union. What were some of the difficulties they encountered?
22. Describe some problems that would occur if the only requirement for a person who wanted to travel into space were to have enough money for the ticket.
23. Guests in an orbiting space hotel, such as the one shown below, would experience microgravity, the sensation of weightlessness.



Describe how weightlessness might affect the following activities associated with hotels on Earth:
(a) eating at a restaurant
(b) sleeping in your room
(c) moving from your room to the lobby area
(d) taking a shower
(e) playing an indoor game of basketball or tennis

Pause and Reflect

In 1998, government officials from 15 countries worked together to create the agenda for running the International Space Station. As technology increases our ability to explore more parts of our solar system, there is a need for discussion about how to coexist in space. Imagine you are in charge of the United Nations task force for space exploration. In a paragraph or two, write a space treaty that discusses the rules of conduct for any nation or private company that wishes to explore space.