Unit 4

Space

CHAPTER 13

Sky-watching and the Solar System

CHAPTER 14

The Nature of the Universe

CHAPTER 15

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Space Research and Exploration

Unit 4 Overview

Have you ever wondered what it would be like to leave Earth and travel far away into the vastness of outer space? How would conditions change as you left Earth? What objects would you discover? Would you find life somewhere else?

13. Sky-watching and the Solar System

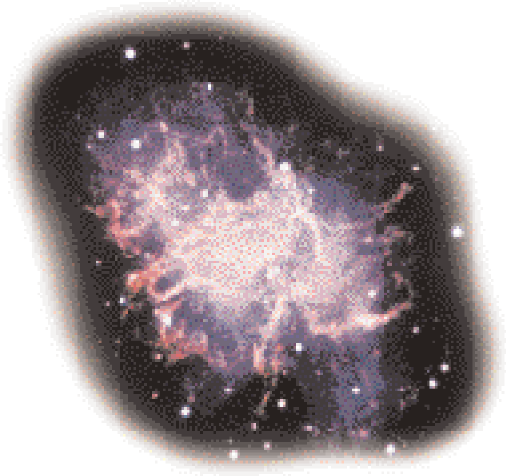
Observation of the stars has affected many human beliefs and activities, including navigation, calendar-making, and the creation of myths.

In this chapter, you will be able to:

- recognize natural objects in the sky
- describe and compare the properties and motions of the components of the solar system and explain how space probes have contributed to our knowledge
- plan ways to answer your own questions about the motion of objects visible in the sky
- conduct investigations into the motions of objects in the sky, and gather, record, and communicate data found during the investigations

14. The Nature of the Universe

The universe is always changing. The many objects that can be found in the universe are in continual motion.



In this chapter, you will be able to:

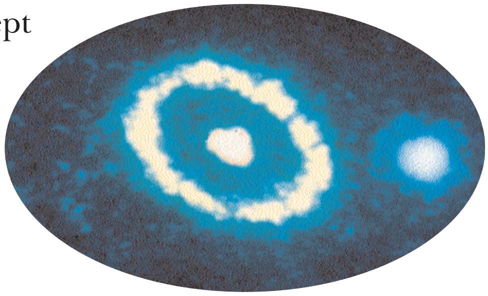
- safely observe the Sun to investigate your own predictions about its motions
- describe and compare properties of stars, including the Sun
- recognize and compare various components of the universe, such as star clusters and galaxies
- research answers to questions about the motion and properties of objects in the universe

15. The History of the Universe

Scientists use models and simulations to visualize and explain the dynamic processes that form the universe.

In this chapter, you will be able to:

- understand how indirect evidence can provide insight to develop models and theories
- describe the life cycles of stars of various masses
- outline the current theory used to explain the formation of the solar system
- illustrate, using models and simulations, the concept of an expanding universe
- examine and evaluate evidence of the origin and evolution of the universe
- describe how computers are used to enhance our understanding of the universe

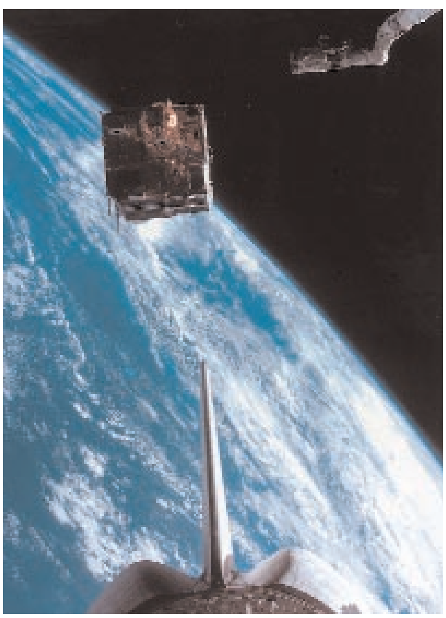


16. Space Research and Exploration

Space exploration and the related technology contribute to our understanding of Earth and the universe and provide many useful applications for life on Earth.

In this chapter, you will be able to:

- interpret data provided by satellites and describe how it contributes to our understanding of Earth and the universe
- simulate and compare the effects of free fall and gravity
- design and plan an experiment that could be conducted in free-fall conditions
- describe Canada's participation in space research and international space programs
- describe and evaluate the spinoffs of space technologies



Challenge

In this unit, you will be able to...

demonstrate your learning by completing a Challenge.

Applying Ideas and Skills of Astronomy and Space Technology

As you learn about what you can see in the sky and how humans explore space beyond Earth, think about how you would accomplish these challenges.

1 Planetarium Shows

Design three shows for a "planetarium" to teach others about astronomy.

2 A Space Research Colony

Design a space colony suitable for permanent human habitation.

3 A Space Technology Information Package

Organize information about space exploration and the study of astronomy, emphasizing their influence on our lives.

To start your own Challenge see page 514.

Record your ideas for the Challenge when you see **Challenge**

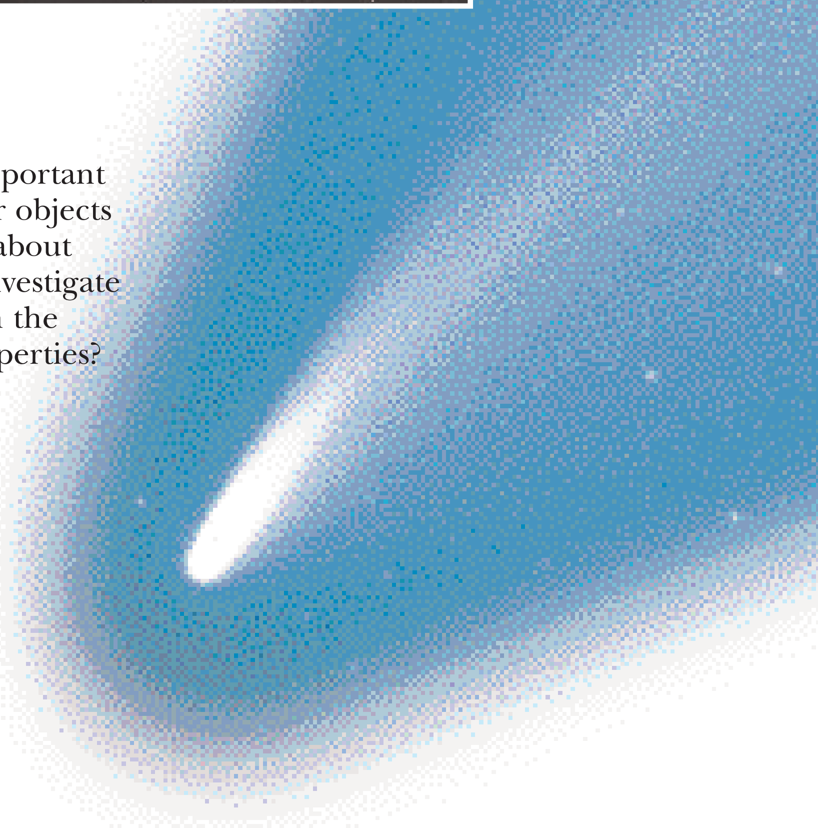
CHAPTER

13 Sky-watching and the Solar System

Getting Started

1. When you first look at the night sky, you probably just see random points of light. Look more closely and more often, and you will begin to see patterns that look familiar. When you look at the stars shown in the photograph, what patterns do you see? Do those patterns change if you hold the book sideways or upside down?

2. You know that the Sun and planets are important objects in the solar system. What are other objects in the solar system, and how do we know about them? What technology are we using to investigate them further? What is the object shown in the photograph, and what are some of its properties?



3. It takes skill and practice to be able to tell the difference between a planet and a star in the night sky. What are the differences? How would you find this information?

4 How would you try to locate a specific star in the sky? Once you have found it, how would you describe to someone else where to look in the night sky to see this object? What information do you think you would need to communicate in order to solve the problem? How has a knowledge of the position of the stars helped travellers in the past?

Reflecting

Think about the questions in 1, 2, 3, 4. What ideas do you already have? What other questions do you have about sky-watching and the solar system? Think about your answers and questions as you read the chapter.

Try This — Modelling the Solar System

You may have already learned something about the solar system and other parts of the universe. To find out what you and your classmates remember, try the following class demonstration.

1. Choose some students to represent the Sun and other objects in the solar system (or beyond, if you wish).
2. Make signs to identify which object each student represents.
3. Simulate the motions of the objects they represent. Each "actor" should explain the motion being made.
4. As a class, discuss how to improve any weaknesses of the demonstration, then try it again.
5. In your notebook, draw a diagram showing the objects and their motion.
6. Also in your notebook, list questions you would like answered in order to improve the demonstration.

13.1

What Can We See in the Sky?

What are some of the objects you can see when you look up into the sky? Of course you can see the Sun and the Moon, and on a dark, clear night you can see many stars. You are also likely to see airplanes and satellites. But have you ever seen Mars and other planets, or moons that travel around planets such as Jupiter? When people begin viewing the sky, and keep records of what they see, they rediscover what many sky-watchers have discovered in the past: there are patterns and rhythms in the slow dance of the night sky.

By studying stars, planets, and other objects in the sky, you will learn where Earth is located in the universe. The **universe** is everything that exists, including all matter and energy everywhere. The study of what is beyond Earth is called **astronomy**.

You don't need a telescope, a camera, or any other special equipment to study the sky. You can start simply by looking at the sky at certain times, learning how to tell stars from planets, and recognizing patterns of stars. This skill can be developed further by looking through binoculars or a telescope.

Star Constellations

When you look up at the sky on a clear night without the aid of binoculars or a telescope, you see countless stars spread unevenly across the night sky. A long time ago, sky-watchers noticed that certain patterns of stars seemed to suggest the shapes of animals, mythical heroes or gods, and other objects. People gave different names to the patterns they saw (**Figure 1**). Groups of stars that seem to form shapes or patterns are called **constellations**. The stars of a constellation may not actually be close to each other. Some stars may be much farther from Earth than others; they just *appear* to be close together.

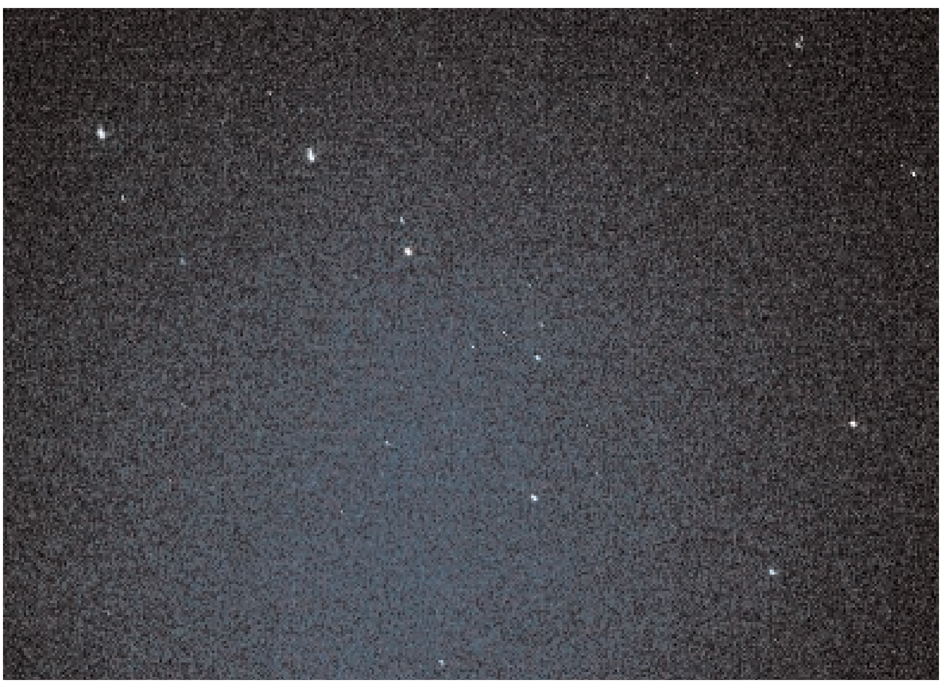


Figure 1

The Big Dipper is part of the constellation Ursa Major, also called the Great Bear. It is probably the best-known group of stars in the Northern Hemisphere.

When you look at a constellation, you may not see the shapes that people in ancient times saw. What looked like a bird to them may look like a cartoon character to you. Today, rather than showing diagrams of animals or people, many books simply show shapes to represent the constellations (**Figure 2**).

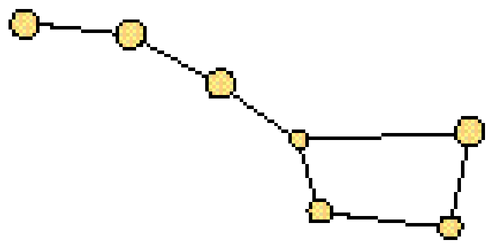
Constellations have been used for thousands of years as calendars, timekeepers and direction finders by people travelling in unknown territory—both on land and at sea. Different constellations were, and still are, used in different parts of the world.

Try This: Looking for Patterns of Stars

Use a star map that represents the stars visible during the winter in Canada. The larger dots represent the brighter stars. On your copy, draw lines between stars that seem to make patterns. The patterns can be animal shapes, geometric figures, cartoon characters, or anything that suggests itself to you.

Objects in the Solar System

You probably already know that the **solar system** consists of our Sun and all the objects that travel around it, including nine known planets and the moons around some of those planets (**Figure 3**). It is easy to see the Sun and Earth's Moon in the sky, although you should never look at the Sun directly. On a clear night, you may also be able to see some of the planets in the solar system. Everything in the solar system is much, much closer to us than the stars and other objects in the universe.



Planets and moons are **nonluminous**: they do not emit their own light. We can see them in the sky only when light from the Sun reflects off them toward Earth. Can you see in **Figure 3** that we would not easily be able to see Mercury in the sky whenever its path takes it close to the Sun? The Sun is very bright, so objects close to it get hidden in the daytime glare.

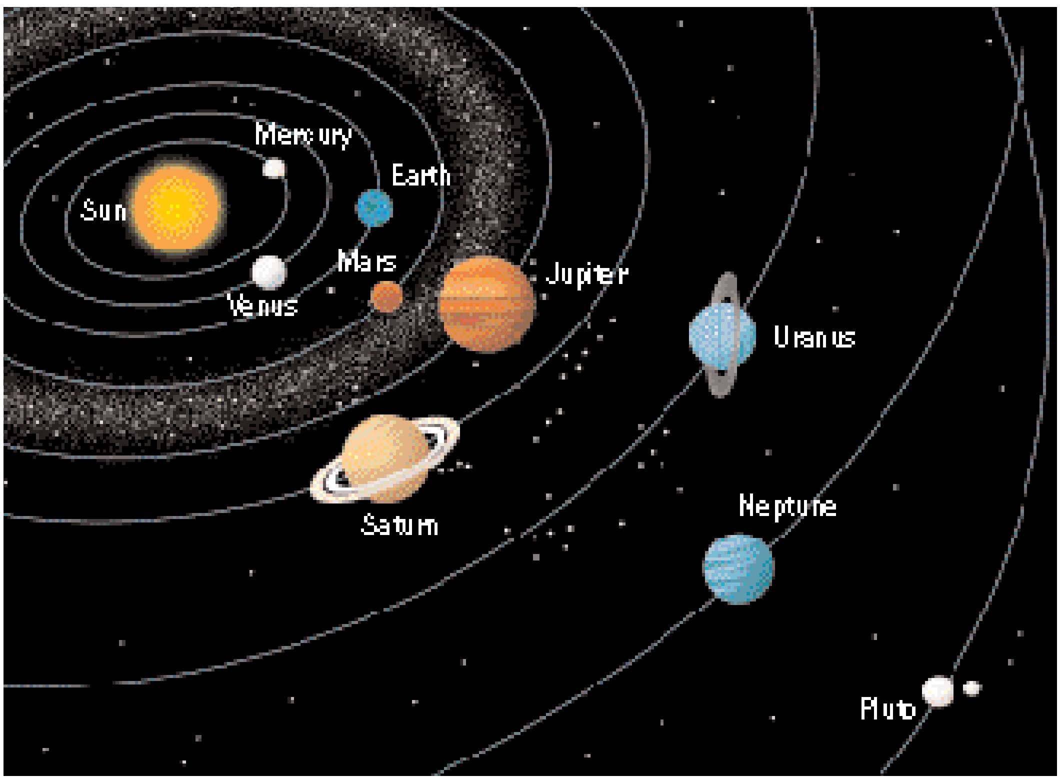


Figure 3
This drawing shows the main objects that make up our solar system. However, it does not show true sizes or distances. For example, the Sun is about 100 times bigger in diameter than Earth.

Observing Stars and Planets

A **star** is matter that emits huge amounts of energy. A **planet** is matter, generally spherical, that revolves around a star. When you look at the night sky, how can you distinguish a planet from a star (**Figure 4**)? Only five of the planets can actually be seen with the unaided eye: Venus, Mars, Jupiter, Saturn, and Mercury. Of these five, planets that are closest to Earth appear through a telescope as somewhat larger than stars. (Stars are very far away, so they look small.) Furthermore, planets appear to have steady light, whereas stars appear to twinkle. **Table 1** summarizes these and other features of stars and planets.

Table 1 Comparing Planets and Stars

Feature	Planet	Star
location	in the solar system	far beyond the solar system
distance from Earth	fairly near	very far
real size	smaller than most stars	usually larger than planets
reason we see object	reflects light from the Sun	emits its own light
surface temperature	usually cool or very cold	very hot
what object is made of	usually rocks or gases	gases under high pressure and temperature
observable feature	does not appear to twinkle	appears to twinkle
long-term observable feature	very slowly wanders through constellations	appears to move through sky as part of a constellation

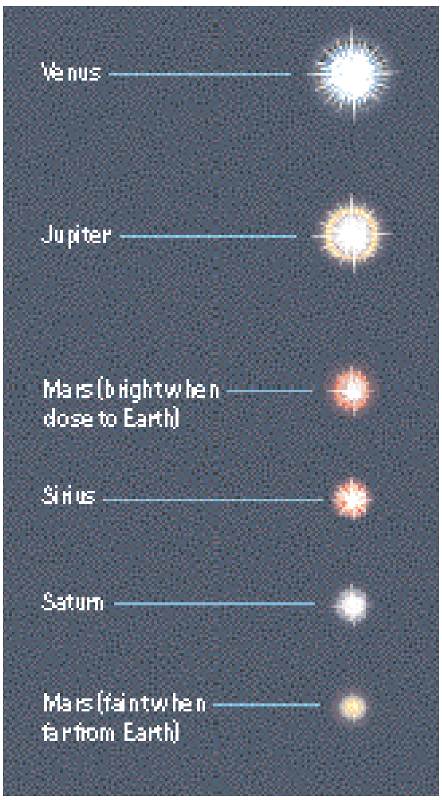


Figure 4
The brightest star in the night sky is Sirius in the constellation Canis Major. It is brighter than the planet Saturn, but not nearly as bright as Venus or Jupiter.

Understanding Concepts

1. The universe is everything that (9D) exists including all matter and energy. Create a concept map of the objects in the universe starting with the word "universe." Keep your map in a safe place so you can use it later.
2. Choose a planet and draw a sketch to show how light travels to allow us to see it.
3. Give at least one reason why
   - **(a)** it is very difficult to see Neptune and Pluto with the unaided eye;
   - **(b)** it is not as common to see Mercury in the sky as it is Jupiter.
4. Prepare an explanation of the differences between a star and a planet for someone who knows little about astronomy.

Making Connections

5. Describe how an astronomer's method of gathering information differs from that of other scientists. Give reasons why.
6. Until fairly recently, people used constellations to help them find their way when they travelled. Why do you think this was possible? Describe a situation where it can still be helpful today.

Reflecting

7. Astronomy is an important area of study. Do you agree or disagree? Give your reasons.

Challenge

Which objects in the universe will you represent in your planetarium shows?

SKILLS HANDBOOK: (9D) Concept Mapping

SKILLS MENU
- ○ Questioning
- ○ Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Sunrise and Sunset

Scientists conduct investigations in a variety of ways. Sometimes they construct experiments to measure and collect their own data. At other times they take previously published data, analyze it, and extract new information. In both cases they ask questions, develop hypotheses, and use many of the skills of planning and conducting an investigation. You can apply the same skills they use as you perform your own research.

Question

How do the times of sunrise and sunset vary in your area throughout the year?

Hypothesis

The day-to-day differences in sunrise and sunset times are the same throughout the year.

Materials

- local newspapers, books, Internet access, or other sources of data on sunrise/sunset times in your area

Procedure

1 Find out the times at which the Sun rises and sets in your area. You could either collect 20 to 50 sets of data for consecutive days, or data for one day of each week for a year.

6D (a) Record your data in a table.

7B (b) Plot your data as a graph.

Analysis and Communication

2 Analyze your results by answering the following questions:

(a) Describe the shape of the curve in your graph.

(b) Answer the initial question.

3 Discuss your results as a class. If different students worked on different times of the year, combine and compare your results. Write a conclusion about how the sunrise and sunset times change throughout the year.

(a) Do your results support the hypothesis?

(b) If necessary, write a new hypothesis.

4 Use a diagram to explain how the results of your graph relate to Earth's motion.

Understanding Concepts

1. How would this investigation performed by a student in Australia compare with your investigation? Explain why.
2. Speculate how the number of hours of sunlight might affect the demand for electricity across various regions of Canada.

Reflecting

3. Imagine you are an early astronomer. Other astronomers think the Sun orbits Earth. They say their model explains the Sun's daily motion across the sky. But you think sunrise and sunset are caused by Earth's motion. Create a model to convince other astronomers.

Challenge

When working on your challenge you will need to use published information. How will you have confidence in the accuracy of your data?

SKILLS HANDBOOK: 6D Creating Data Tables 7B Constructing Graphs

The Effects of Planetary Motion

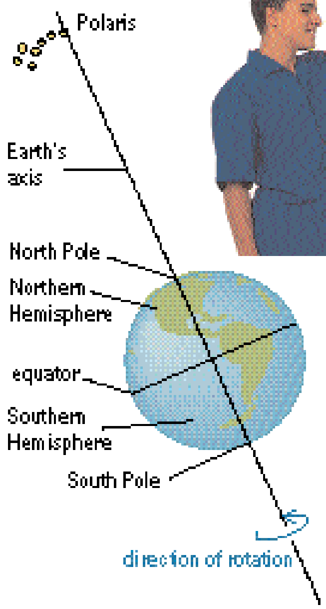
Effect of Earth's Rotation

If you watch the sky at night for at least an hour, you will notice that the positions of the stars and planets slowly change. Like the Sun, most stars appear to rise in the east, travel across the sky, and set in the west. You can understand these changes by thinking about Earth's motion.

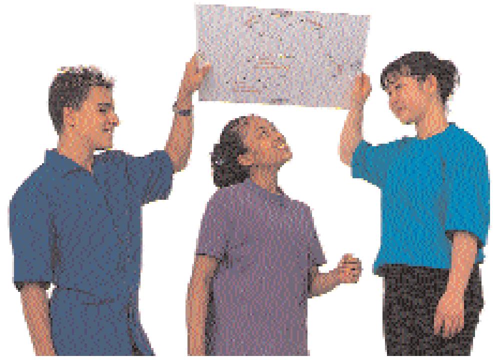
One type of motion of Earth is called **rotation**, which is the spinning of an object around its axis. One rotation of Earth takes 24 h. This motion causes most stars (as well as the Sun, Moon, and planets) to appear to rise in the east and set in the west.

Earth's **axis** is an imaginary straight line joining the North Pole and the South Pole. If the axis were continued northward, out into space, it would pass almost through Polaris, the North Star. **Figure 1a** shows why people who live in Canada are able to see Polaris all year long. As Earth rotates, the stars near Polaris seem to travel in circles around Polaris. **Figure 1b** shows a way of demonstrating this.

Figure 1



a Polaris is visible from Canada all year long. People south of the equator cannot see Polaris or any of the stars near it. Are there stars that Canadians never see?



b This is one way of showing how Earth's rotation causes stars to appear to travel. As you are standing, look at Polaris (the North Star) and slowly spin counterclockwise (from the sky's view). You should notice that the stars appear to move in circles around Polaris.

Did You Know

Has anyone ever asked you what "sign of the zodiac" you were born under? Your answer may be one of 12 signs, such as Aries, Taurus, Leo, or Scorpio. These signs are named after the zodiac constellations.

Effect of Earth's Revolution

Another type of motion of Earth is **revolution**, which is the movement of one object travelling around another. It takes Earth one year to travel, or revolve, in a circle around the Sun. This motion enables us to see different stars and constellations during different seasons, as shown in **Figure 2**. Combined with the angle of Earth's axis, Earth's revolution also causes the seasons.

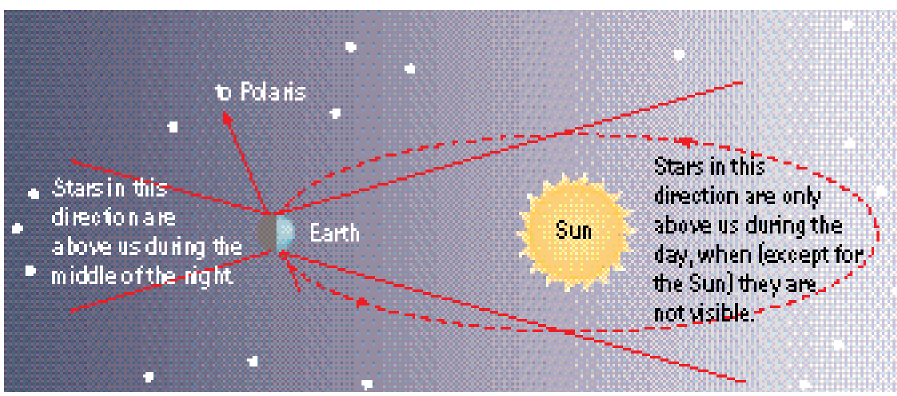


Figure 2

For observers in the Northern Hemisphere, the only constellations we can see in all seasons are those that appear close to Polaris. We can see the other constellations only when they are not in the sky at the same time as the Sun.

Effect of Planets' Motions

In ancient times, when there were no city lights to spoil people's views and no televisions to occupy their evenings, people were more aware of the night sky than most people are today. Even then, astronomers noticed that the bright objects in the sky moved, and that those in constellations moved together. They saw that five particularly bright points of light moved differently when compared with the other stars. They called these objects "wandering stars," or planets, from the Greek word *planetes*, meaning "wanderers." We now know that the reason for the changing positions is that the planets are travelling around the Sun and they are much closer to us than the stars in the background.

The planets appear to move through certain constellations, many of which were named after animals. Since the Greek word for "animal sign" is *zoidion*, the constellations were called the **zodiac constellations**. Thus, another way to distinguish a planet from a star is to observe its motion over weeks or months.

Try This — You Are Earth

Make your classroom into a planetarium. Place diagrams of the Big Dipper, the Little Dipper, and Cassiopeia on the ceiling. Place these four constellations on the walls:

- Aquila (summer) on the east wall
- Pegasus (autumn) on the north wall
- Orion (winter) on the west wall
- Leo (spring) on the south wall

Choose one person to represent the Sun in the middle of the room. Pretending you are Earth, stand east of the Sun and slowly spin around counterclockwise. When your back is toward the Sun, it is night on Earth. Aquila and the constellations above the Sun are visible. As you spin around to daytime, the other constellations may be located near the horizon, but you can't see them because the sunlight is too bright. Try this at locations north, west, and south of the Sun.

Understanding Concepts

1. Where do stars "rise" in the night sky?
2. Describe and compare Earth's rotation and revolution.
3. Explain why a constellation
   (a) appears to change position from hour to hour during the night;
   (b) is at a different location at the same time on different nights.
4. In **Figure 3**, the stars appear to revolve around a single spot. Where was the camera pointed?

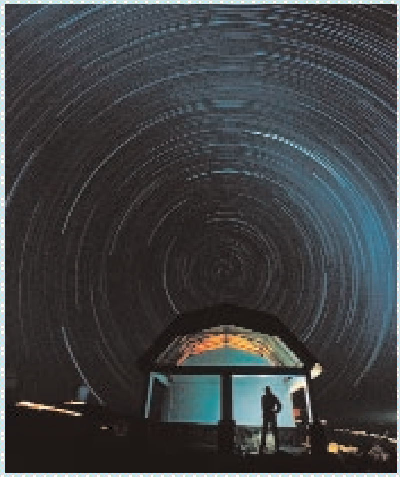


Figure 3
Night sky observed in the Northern Hemisphere

Making Connections

5. What would be the difficulties of using stars to indicate direction while travelling? Would one star be more useful than any of the others?

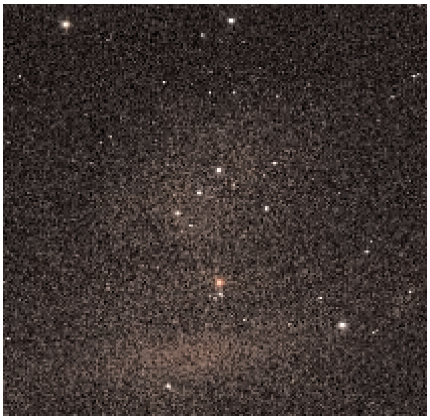
Challenge

How can the model suggested in this section help you design a model of a planetarium?

Recognizing Constellations

In this activity, you will develop skill in recognizing some constellations like Orion (**Figure 1**). As you do, think about what sailors experienced hundreds of years ago when they relied on stars to find their way across the northern oceans. Why was the North Star the most important star in the sky to them?

Figure 1
To some people in ancient times, this constellation looked like a hunter whom they called Orion.



Materials

- copy of star map
- ruler

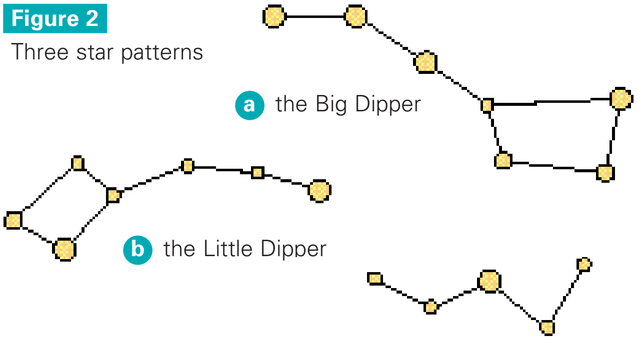
Procedure

Part 1: Three Year-Round Constellations

1 **Figure 2** shows the shapes of three star patterns that you can see in the Canadian sky all year. Near the middle of the star map, locate the Big Dipper in the constellation Ursa Major. (5C)

(a) Use a ruler to draw lines joining the stars that make up the Big Dipper.

Figure 2
Three star patterns



2 Near the upper-centre of your star map, locate the Little Dipper and the star at the tip of the handle. This important star is called Polaris, or the North Star. Anybody in the Northern Hemisphere looking toward Polaris is facing toward the North Pole.

(a) Draw straight lines joining the stars that make up the Little Dipper. Label Polaris.

3 Find the two stars of the Big Dipper that are farthest from the handle.

(a) From these stars, use a ruler to draw a dashed line to Polaris. This line shows how to use pointer stars to locate other stars or constellations. (This is important when you try to view the night sky because the Little Dipper is not nearly as bright as the Big Dipper.)

4 From the same pointer stars you used in step 3, continue past Polaris until you are close to Cassiopeia, a constellation in the shape of a spread-out *W* or *M*.

(a) Draw straight lines joining the stars that make up Cassiopeia.

5 Identify the three constellations you have found.

(a) Ask your teacher to check your star map now. Label the constellations.

Part 2: Seasonal Constellations

6 **Figure 3** shows constellations that you can see in the night sky over Canada during the winter months. The easiest one for you to see is the constellation Orion, with three bright stars that line up to make this imaginary hunter's belt. Locate Orion on your star map. It is near the part of the map marked winter. This means that Orion can be seen most easily in

SKILLS HANDBOOK: 5C Using Star Maps

December, but it can also be seen in November and January.

(a) Draw straight lines joining the stars that make up Orion. Label Orion as well as the bright stars in Orion: Rigel and Betelgeuse.

7 Use the stars of Orion's "belt" as pointers to locate the brightest star in the night sky, Sirius.

(a) Draw a dashed line on your map to show this method. Also draw Canis Major, the constellation in which Sirius is found.

8 Locate the constellation Boötes.

(a) Draw the lines joining the stars of this constellation. (The bright star Arcturus is part of this constellation.)

(b) Describe how you could use the stars of the handle of the Big Dipper as pointers to find Arcturus. Draw a dashed line on your map to illustrate this method.

9 Leo is located about midway between Canis Major and Boötes, and contains the star Regulus.

(a) Draw the constellation Leo on your map.

(b) Describe how you could use two stars of the Big Dipper as pointers to locate Regulus. Show this with a dashed line on your map.

10 Find the three bright stars Deneb, Vega, and Altair.

(a) Join them with dashed lines to show the Summer Triangle. Draw the constellations to which Deneb, Vega, and Altair belong: Cygnus, Lyra, and Aquila.

11 Locate the constellations Andromeda and Pegasus. You can find these constellations by starting from Polaris and going past Cassiopeia.

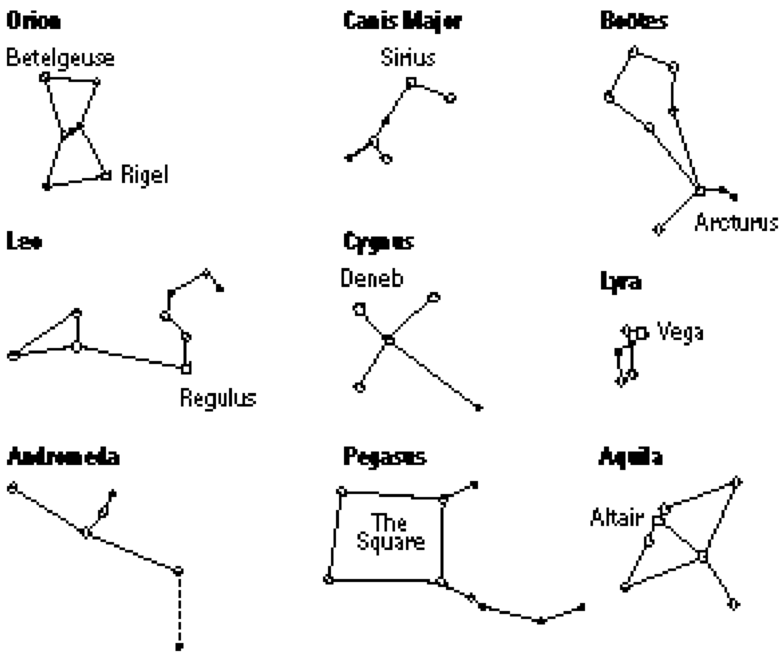


Figure 3

You can see these nine constellations only during certain seasons. Where are they at other times of the year?

(a) Draw and label Andromeda and Pegasus. Also label the Square of Pegasus.

Understanding Concepts

1. Why was Polaris important to early sea navigation?
2. Is Polaris still important to observers in the Northern Hemisphere?
3. Would people in Australia be able to see Polaris? Explain your answer with a diagram.
4. What are "pointer stars" and why are they useful?

Making Connections

5. If you were looking for stars while surrounded by bright city lights, which stars would you try to find first? Why?

Exploring

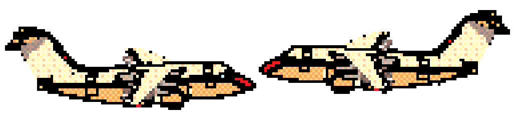
6. (3A) To know their exact location at sea, sailors often use two instruments: the sextant and the chronometer. Find out when these instruments were invented, how they were used, and how effective they were in determining location.

(3A) Research Skills

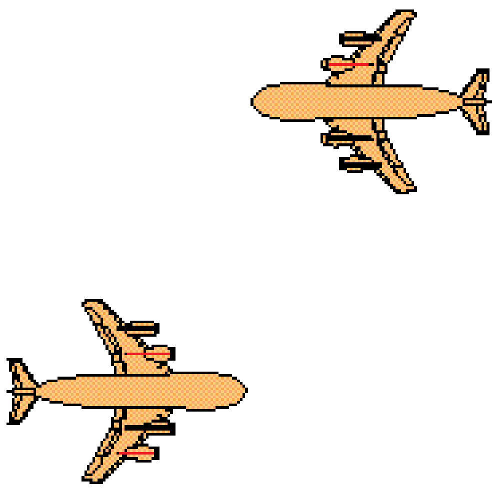
Measuring Angles in the Sky

When we are looking at things that are far away, it is hard to describe their location. For example, if you're looking at two airplanes coming toward each other at an air show, it's hard to judge how far apart they are. Sometimes it looks as though they're about to collide, even though they may be quite far apart, as shown in **Figure 1**. They seem close together because the angle between them is small. In this activity, you will use two ways to describe the location of distant objects using angles.

Figure 1
From one point of view, these aircraft look close together. From another point of view, they are clearly quite far apart.



a From the side they seem about to collide.



b From below there is clearly a horizontal distance between their wingtips.

Materials

- thin cardboard
- small protractor
- ruler
- pencil
- scissors
- string
- rubber stopper
- tape
- drinking straw

Procedure

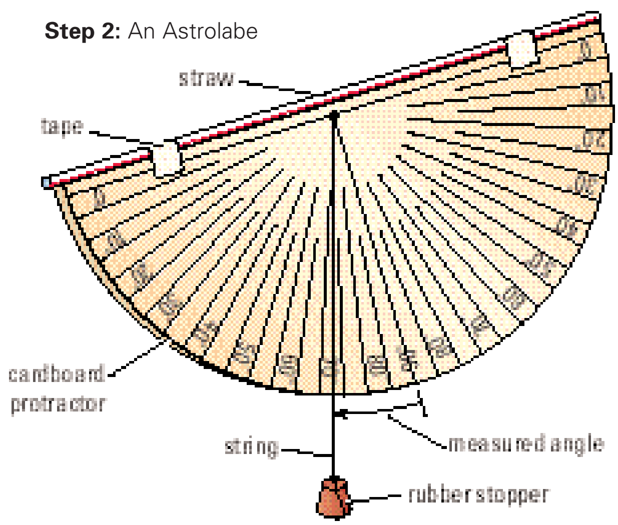
1 Set up a data table based on **Table 1**. Two examples are given for reference. You will choose and record your own observations.

Table 1

Viewing location	Description of angle measured	Angle using astrolabe	Angle using hand method
edge of playing field	angle between the horizontal and the top of the nearest tree	26°	25°
height of roof	angle between the bottom and top of a roof	28° – 21° = 7°	8°

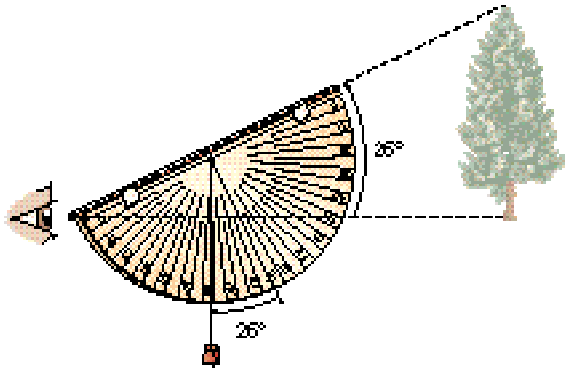
2 Using the illustration for reference, design and build an astrolabe. Start by drawing a large protractor on thin cardboard, then cut it out.

Step 2: An Astrolabe



3 Use the astrolabe to measure the angle between the horizontal (eye level) and three or four objects in the classroom or outdoors. Use the diagram in step 3 to help you see how to measure the angles.

(a) Record the data in the first three columns of your table.

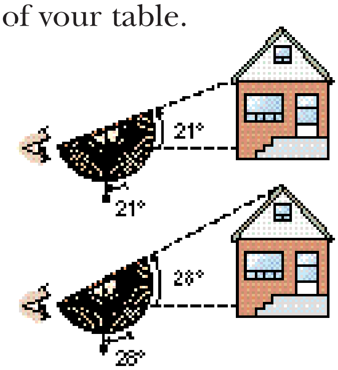


Step 3: The angle on the astrolabe gets bigger as you look higher in the sky. In this case, the angle on the astrolabe equals the angle between the horizontal and the top of the tree.

4 Practise using the astrolabe to measure the angle between two parts of the same object. Remember that the horizontal angle is 90° minus the reading on the astrolabe. For example, you can find the angle between the bottom and top of a roof, as shown. Do this for three or four situations.

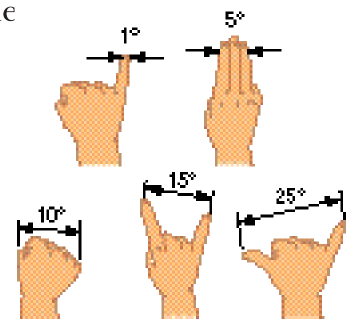
(a) Record the data in the first three columns of your table.

Step 4: Use subtraction to find the angle between objects.



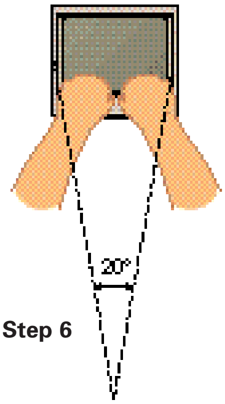
5 Learn how to use your outstretched arm and different parts of your hand to measure angles. The illustration below shows how to do this. Then repeat the measurements you made in steps 3 and 4.

(a) Record the data in column 4 of your table



6 Use the hand method to measure the horizontal angle between two positions. One example is shown.

(a) Record the data in your table.



Step 6

7 Compare the astrolabe method and the hand method.

(a) Which method, do you think provided better angle measurements? Explain why.

(b) Which method works better for measuring horizontal angles? Why?

8 Compare the answers you found with those other students found for the same angles.

Understanding Concepts

1. What is meant by the statement "The Big Dipper is 25° long"?

Making Connections

2. A traveller in pioneer times wanted to cross a lake, in a direction 20° east of north. How might he or she have kept on course?

Exploring

3. How many "fists" are required to measure
   (a) a right angle?
   (b) from the eastern horizon to the western horizon going across the sky?
   (c) from the east to the west going around the horizon?
   (d) a complete circle?
4. Use the hand method to measure the angle from the horizontal and a point directly above your head. Compare your angle with 90°.
5. Predict what happens to the angle between two objects as you get farther away from the objects. Design an activity to check your prediction.

Different Views of the Sky

In your science course, you are responsible for learning concepts, developing skills, and applying your knowledge and skills. Many cultures also developed concepts, skills, and applications as they investigated the sky and developed their own ideas of the universe.

A Variety of Ideas

Evidence found in caves and tombs and on pottery shows that people studied astronomy thousands of years ago. This makes astronomy one of the oldest of the sciences (**Figure 1**).

Figure 1
This ancient Aztec carving shows that Aztec astronomers studied the sky and were familiar with many constellations.

People all over the world have used legends (traditional stories) to explain events and objects in nature. Canadian First Nations peoples have many legends that describe the Sun, stars, Moon, planets, and special events such as eclipses and meteor showers.

- The Menomini of the Great Lakes region tell this legend about meteors: "When a star falls from the sky it leaves a fiery tail. It doesn't die; rather its shade goes back to shine again."
- The Kwakiutl of the West Coast region believed that a lunar eclipse occurred when the sky monster tried to swallow the Moon. By dancing around a smoky fire, they hoped to force the monster to sneeze and cough up the Moon.
- The Tsimshian, also of the West Coast, believed that each night the Sun went to sleep in his house but allowed the light from his face to shine out of the smoke hole in the roof. The stars were sparks that flew out of the Sun's mouth. The full Moon was the Sun's brother who rose in the east when the Sun fell asleep.

(a) What evidence supported each belief?

(b) Identify the concept behind each legend. What does the story say to the listeners?

Developing Skills

About 7000 years ago, people began settling on farms and in towns. They began using the regular cycles of the Sun and Moon to plan a calendar. The calendar helped them decide when to plant and harvest crops, and when to hold their feasts. Astronomers developed great skill in mapping the night sky.

- More than 3000 years ago the Chinese developed a very accurate calendar of 365 days by using their observations of the Sun and stars. They recorded comets, meteors, and what they called "guest stars." (We now know that these are exploding stars, which are visible for a few weeks or months.) Both the Chinese and the Greeks created star maps more than 2000 years ago, showing the position and approximate brightness of more than 800 stars. They did this using only their eyes and some instruments to measure angles.

- The Maya are a native people who live in Central America. Over 1000 years ago they had developed ways of accurately keeping track of the movements of the planets. Many of their temples were used as observatories. One of the few remaining ancient Mayan books shows that the Maya were able to predict the appearance of Venus very accurately: their predictions were off by only two hours in 500 years.

(c) What skills must Chinese and Greek astronomers have acquired, before they could construct their calendars?

(d) List ways that a calendar may have helped people in ancient times.

(e) List several ways that a calendar helps you organize your life.

(f) There were excellent astronomers among the Chinese, Greeks, and other peoples in ancient times, yet their star maps contained only about 800 stars. What prevented these ancient astronomers from cataloguing more stars?

Evidence of Applications

Permanent structures built thousands of years ago verify that people applied their knowledge of astronomy to help them predict events.

- In Egypt, a pharaoh's temple was designed with a long, narrow entranceway through which the Sun's rays shone directly onto a statue of the pharaoh on two special days of the year: one in February and the other in October.
- A stone structure called Stonehenge was built in England about 5000 years ago (**Figure 2**). Historians believe its purpose was to indicate the longest day of the year and to predict the occurrence of eclipses.

(g) If the Egyptian statue was in sunlight for only two days of the year, the Sun must be in that position only on those days. How might ancient astronomers have discovered this fact?

Figure 2
The huge stones of Stonehenge are arranged in a well-organized pattern. After many years of studying the pattern, scientists think that the people who built Stonehenge used the pattern to predict repetitive events.

Making Connections

1. In Canada the Sun is highest in the sky on the first day of summer and lowest on the first day of winter. Use this information to design a simple calendar.

Exploring

2. What kind of instrument might ancient Chinese (3A) astronomers have used to measure angles? Propose a design, then research the original design. Compare the two.
3. Research ancient astronomical achievements until the end of the Roman Empire. Place these on a time line.
4. The reason we have a day-and-night cycle is that Earth rotates on its axis once every 24 h. Create a legend to give a different reason for this cycle.
5. Research information about Canadian First Nations' understanding of calendars and astronomy.
6. Find out why the Maya were so interested in Venus that they developed an accurate way to predict its appearance.

Reflecting

7. Compare and contrast how ancient peoples viewed the sky with your own modern view.

A Seasonal Star Map

A skill that is useful in everyday life is reading a map. As you use a star map to find directions and star locations, you will improve your skill at reading other types of maps. Like a street map, a star map is a tool that helps you to identify what is around you. In this activity you will build your own seasonal star map, similar to those used since early times for navigation. You will learn how to use it in the classroom before you try it outdoors.

Part 1: Building a Seasonal Star Map

Materials

- copy of seasonal star map
- cardboard
- scissors
- glue stick
- copy of star map "window frame"
- piece of acetate as large as the window frame
- paper fastener
- phosphorescent paints (optional)

Be careful when using scissors. Also, if you use any phosphorescent paints, be sure to follow the instructions on the container.

Procedure

1 Using **Figure 1** as a reference, cut out the seasonal star map and a piece of cardboard the same size. Glue the map onto the cardboard. Make a hole in the centre for the paper fastener. (5C)

2 Add all the dashed lines needed to show the use of pointer stars, as you did on the star map in Activity 13.4.

3 If possible, use one colour of phosphorescent paint to highlight the constellations on the star map and another for the labels on the window frame and the star map. (This will help you see the map in the dark for a few hours after the painted parts have been in bright light.)

4 Cut out the window frame, including the actual window from the star map window frame. Glue the window frame to the piece of acetate. Cut the outer part of the acetate, but do *not* cut the window out of the acetate. In the centre of the circle, make a hole for the paper fastener.

5 Use the paper fastener to fasten the acetate to the star map. Be sure the window frame can rotate freely.

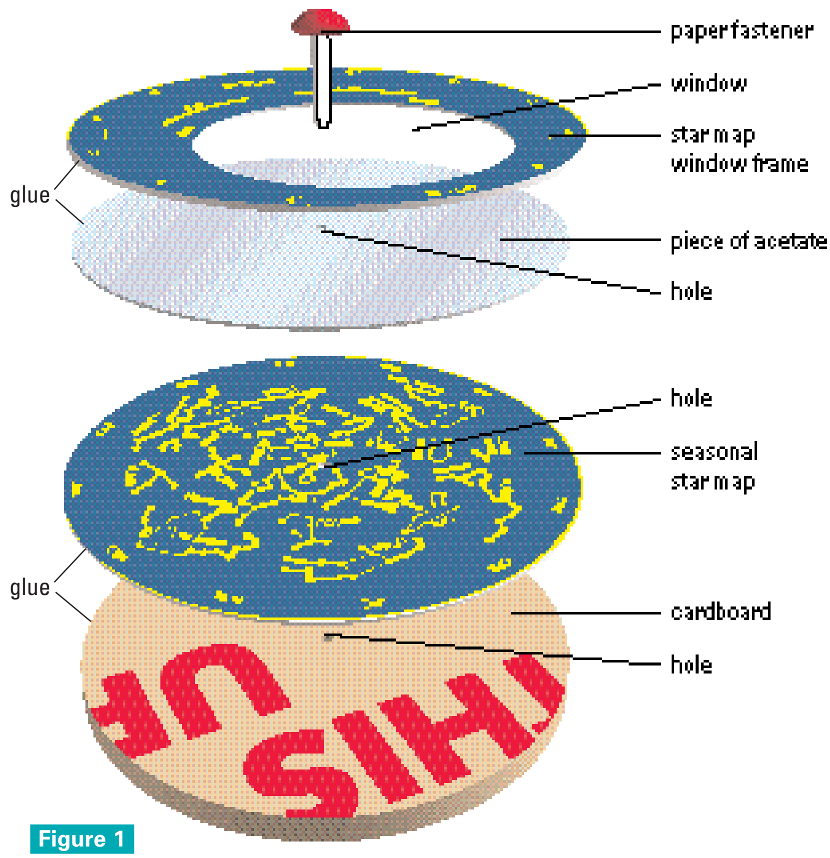


Figure 1
Assembling the seasonal star map

Part 2: Using the Seasonal Star Map

Materials

- the seasonal star map assembled in Part 1

Procedure

6 While in your classroom, pretend you are outdoors. Decide which directions in the room are east, west, north, and south.

(a) Record which wall in the room is the south wall.

7 To learn how to use the map at midnight on December 15, rotate the window frame so "midnight" is in the middle of December. Hold the map over your head, map facing downward, with the middle of the window directly above your eyes and "midnight" pointing north. What you see on your star map is what you would be able to see in the night sky.

(a) Predict which constellations you would be able to see near each horizon: north, south, east, and west.

(b) Predict which constellations you would be able to see high above your head.

8 Compare your predictions with those of other students.

(a) Based on your discussions with other students and your teacher, make changes to your predictions.

9 Repeat steps 7 and 8 for midnight on May 15.

(a) Record your predictions.

10 If you look at the sky before midnight, the stars you expect to see will be rising in the east. If you look at the sky after midnight, the stars you expect to see will be setting in the west. To prove this to yourself, set your star map at 8:00 p.m. on December 15.

(a) Describe what you discover.

Understanding Concepts

1. As you rotate the window frame, which constellations can be seen no matter what the month is?
2. Name the constellations that are visible nearer the horizon at midnight in (a) July and (b) March.
3. How would you adjust the window frame if you were using the seasonal star map on different dates of the same month, such as November 1, 15, and 30?
4. Name the constellations that have at least one very bright star in them and would be easier to identify in the sky than other constellations.
5. Pretend that a star is located where the front wall of your classroom meets the ceiling. Determine its angle above the horizontal from where you are located.

Making Connections

6. In societies where calendars are uncommon, the seasonal positions of the constellations are used to indicate when various festivals or activities should take place. If a crop has to be planted in October, what constellations should a North American farmer look for?

Exploring

7. Use resources to find out which planets are visible in the sky during the current month. Describe how you would try to find a planet in the sky if you went observing now.
8. A planisphere or star finder is a device designed to show the stars and constellations of the current night sky at any time, or season, during the year. Check all your local newspapers for an astronomy column with star maps, or the Canadian publication *SkyNews*. Compare your star finder with the star maps you found.

Challenge

How would a seasonal star map be a useful tool in the planetarium challenge? How would a tool like this be of use in your space colony?

Observing the Night Sky

When you gaze at the night sky, you are doing what millions of people have done for thousands of years. However, when you observe carefully, taking measurements and keeping notes, you are following in the footsteps of a much smaller group, but one almost as ancient.

Ever since people developed techniques for writing and map-drawing, dedicated astronomers have kept records of changes in the night sky.

In this activity you will use the seasonal star map. Of course, the sky will look very different from the star map because there are many more stars in the sky than on your map. However, with some practice, you can become just as skilled as the ancient astronomers in observing the stars.

Part 1: Getting Ready to Stargaze

Choose an evening when you can see the stars clearly. Follow the Procedure steps outlined below.

Materials

- copies of observation sheets

Procedure

1. You will need an observation sheet. Use the following headings: Date; Time of Observation; Constellation Seen; Diagram of Pattern; Angle above the Horizon; Direction; Questions I would Like Answered.
2. Organize the materials you will need for the trip. Refer to the list of materials suggested for Part 2.
3. As a group, and with the assistance of an adult, plan the trip. Choose a safe location, free from hazardous terrain. Consider when and where you will meet and who will bring the materials. Also consider the weather forecast and the safety of the group.

Part 2: Stargazing

Materials

- appropriate outdoor clothing
- compass
- seasonal star map
- flashlight
- red cellophane (to cover the flashlight)
- telescope or pair of binoculars (if available)
- astrolabe (if available)
- compass (if available)

When you go stargazing, get prior permission from your parent or guardian, and always go in a familiar group.

Procedure

4. On a clear, preferably moonless, night after you are able to see the stars, go to a dark location away from bright lights. Allow your eyes at least 10 min to become used to the darkness. Organize the materials so you can begin observing.
5. 5C Use the compass to find north. Set the map to the current date and time. Hold the star map up over your head, with "midnight" pointing north. Use your covered flashlight to look at the map **(Figure 1)**. Compare what is in the sky with what is on the map.

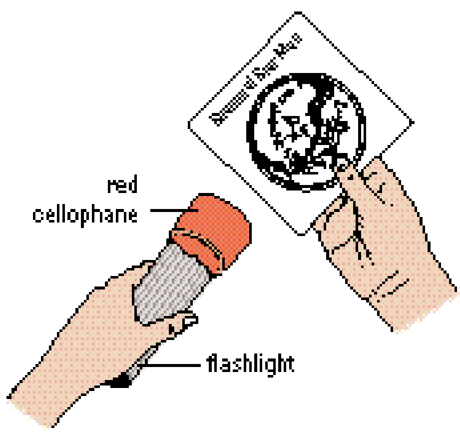


Figure 1
When using a flashlight to view a star map, it is best to cover the light with red cellophane. If you didn't cover the light, how might it affect your eyes?

SKILLS HANDBOOK: 5C Using Star Maps

6 Find the Big Dipper on the map. Then locate the Big Dipper in the sky.

(a) Record your observations. When you draw any diagram, include objects near the horizon for reference. When you measure angles, include the angle above the horizon as well as angles between the ends of the constellation. For example, at 9:00 p.m. on a certain night, the belt of Orion may be two "fists" above the horizon. Record your reading in degrees.

7 Use the two pointer stars from the Big Dipper to locate the North Star, Polaris. Find the Little Dipper, first on your map and then in the sky.

(a) Record your observations.

8 Find Cassiopeia on the side of Polaris opposite the Big Dipper.

(a) Record what you observe.

9 Look for other constellations, bright stars, and planets. When you observe a planet, record its position relative to nearby constellations. (Remember that planets do not appear to twinkle the way stars do.)

(a) Record your observations. Include any questions you have in your table of observations. For instance, you might observe a pair of equally bright stars one night, but the next night they might not be equally bright. You could ask, "Which star has changed its brightness?" You may have other questions about the planets, the moons of planets, meteors, satellites, or other objects in the sky.

10 If possible, use a telescope or a pair of binoculars to look at a specific star.

(a) Record what you see.

Understanding Concepts

1. In your opinion, what are the most important constellations for beginners to recognize? Why do you think so?
2. Why is star-watching difficult in cities and towns?

Exploring

3. Compare the angle between the northern horizon and Polaris with the latitude of your location (found on an atlas or a globe). What do you conclude?
4. (4B) Plan an investigation to determine how the positions of constellations and planets change over a period of several weeks. Include safety precautions. Have your teacher approve your plan, then carry it out. Keep a record of what you discover.
5. Find a computer software program that simulates the motion of the constellations and planets in the sky. Observe what happens as the program advances by some period of time, such as two weeks. Explain what you observe.

Reflecting

6. The night sky has always inspired people to create stories, music, and images. Choose a piece of sky-inspired art. What is your personal response to it?
7. Astronomy is an observational science not an experimental science. Do you agree or disagree with this statement? Give supporting reasons for your viewpoint.

(4B) Designing a Procedure

Light Pollution

When you look up at the night sky from a city, you can see far fewer stars than if you are in a rural location. In fact, you will probably only ever see the brightest stars and planets. Why is this? It is because of the amount of artificial light around us. Every light source sends some of its light directly where we need it, and some where we don't. The light that is not used is wasted. In particular, light that shines upward reflects off hard surfaces and clouds, and is scattered by molecules and dust particles in the atmosphere. It may end up making the night sky up to 100 times brighter above a city than it is in an unpopulated, unlit rural area. This unused light is called **light pollution**.

Why Is Light Pollution a Problem?

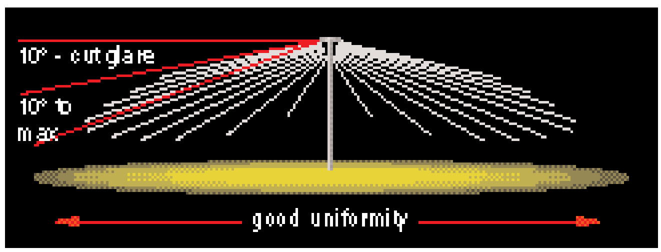
- Astronomers and skywatchers are frustrated in their attempts to study the night sky by the amount of artificial light entering their eyes or telescopes. Just as it is difficult to see a candle flame in a brightly lit room, it is almost impossible to view distant stars through an atmosphere glowing with light from nearby towns and cities.
- It is a waste of energy. If 30% of the light output from outdoor lighting goes up into the sky, instead of down toward the street, we are using 30% more energy than we need to. This translates into a waste of money.
- Unnecessary light that travels horizontally can glare into the eyes of motorists, making it difficult for drivers to see obstacles, and thus causing a road safety hazard.
- Glare from poorly shielded lights may shine into the windows of homes, where it can be an unpleasant nuisance.
- Environmentalists are concerned about the number of migratory birds that are killed each year. The birds are dazzled by city lights and then fly into lighted windows.

How Can Light Pollution Be Reduced?

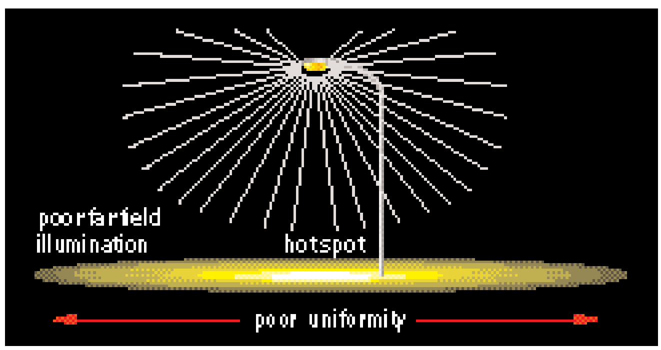
People with many different interests are trying to get light pollution reduced. There are several ways to achieve this.

- Persuade owners and operators of large office buildings to turn off most of their lights at night.
- Install better shielding around streetlights so the light is directed downward, to the street, not up into the sky.
- Design lighting systems that produce uniform illumination, reducing the depth of shadows (**Figure 1**). This would allow us to use lower light levels.
- Inform private users of electricity about the issues, and educate them to use only what light they need, where they need it. For example, lighting an outdoor car lot at night, if there is nobody there guarding it, is just helping thieves to see better!

Figure 1



(a) "sharp cut-off" luminaire



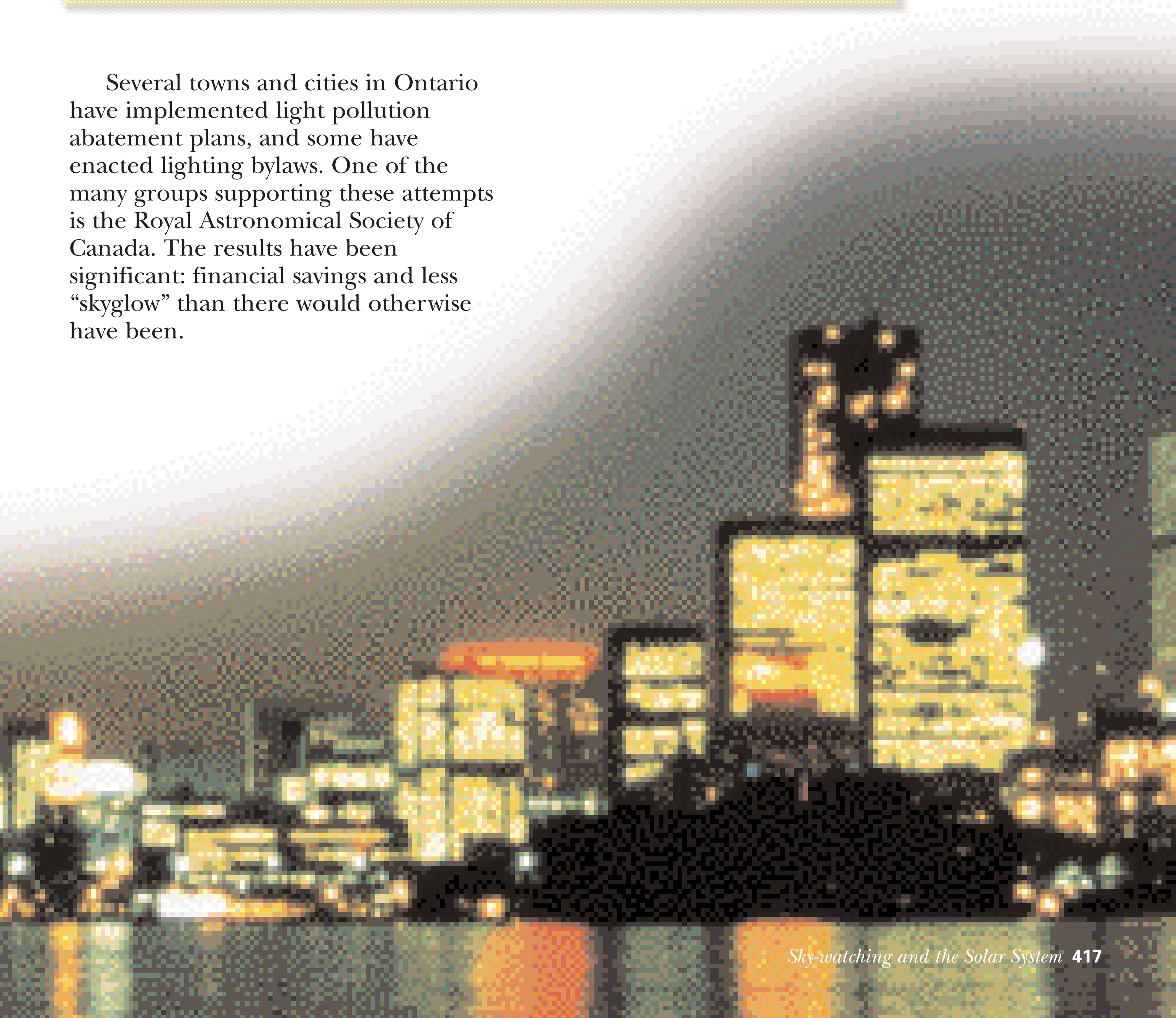
(b) "standard cobra" luminaire

SKILLS HANDBOOK: 8B Exploring an Issue

Issue: What Can Be Done? (8B)

- You are a member of an astronomical society. Pick one approach to reducing light pollution. It can be one of those already mentioned or one of your own choosing.
- Write a proposal to the person or organization responsible for the lighting to persuade them to reduce the amount of light pollution.
- Include arguments to support your proposal. You will need to research your topic and provide some reasonable suggestions for alternatives. Be sure to mention the benefits that will result.
- Consider any counterarguments, and try to address these also.
- When your proposal is complete, write it out and send it to the chosen person or organization.

Several towns and cities in Ontario have implemented light pollution abatement plans, and some have enacted lighting bylaws. One of the many groups supporting these attempts is the Royal Astronomical Society of Canada. The results have been significant: financial savings and less "skyglow" than there would otherwise have been.



13.10

The Solar System

Imagine that the year is 2025, and you are part of a team that is designing a space colony on another planet where humans will live. Which planet in the solar system would you choose? To make a wise decision you need to know, among other things, the characteristics of the planets.

Each planet in the solar system is unique. The planets differ in their size, motion, and temperature, in the substances they are made of, and in their gravitational field strength. These properties are described below and summarized in **Table 1**. As you look at the properties of the planets, think of ways that the planets can be grouped. Especially consider which planets are most similar to Earth.

At the centre of our solar system is a star that is essential to our life on Earth—the **Sun**. The planets revolve around the Sun in paths called **orbits**. The orbits of most planets are nearly circular, with the Sun at the centre of each orbit. The period of time for one revolution around the Sun is called one **orbital period**. Earth's orbital period is about 365 days.

Besides revolving around the Sun, each planet rotates on its own axis. Earth's rotation around its axis once every 24 h causes our day and night cycle.

Did You Know ?

The planets' orbits are actually shaped liked slightly flattened circles. The mathematical name for this shape is an *ellipse*, so the paths are *elliptical orbits*. An ellipse has two focal points (points around which it is centred). The Sun is located at one of the focal points for all the planets' orbits.

Table 1 **Properties of the Planets in the Solar System**

Properties	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
average distance from Sun (x 10^6 km)	57.9	108	150	228	778	1427	2870	4497	5900
orbital period	88.0 d*	224.7 d	365.26 d	687 d	11.9 a**	29.5 a	84.1 a	164.8 a	247.7 a
average diameter (km)	4880	12 100	12 750	6790	142 800	120 700	50 800	48 600	2300***
time for one rotation	59 d	243 d****	24 h	24 h 39 min	9 h 50 min	10 h 39 min	17 h 18 min****	15 h 40 min	153 h 18 min****
main substances in the atmosphere	none	carbon dioxide, nitrogen	nitrogen, oxygen	carbon dioxide, nitrogen	hydrogen, helium, methane	hydrogen, helium, methane	hydrogen, helium, methane	hydrogen, helium, methane	none
mean surface temperature (°C)	–180 to 426	470	–85 to 58	–120 to 30	–160	–180	–210	–220	–220
density (g/cm^3)	5.44	5.25	5.52	3.95	1.31	0.70	1.18	1.66	1.1***
surface gravity (Earth = 1)	0.39	0.90	1.0	0.38	2.58	1.11	1.07	1.4	0.08***

* The symbol "d" stands for day. It means one Earth day.
** The symbol "a" stands for year (from annum, the Latin word for year). It means one Earth year.
*** This is an estimate. Little is known about Pluto.
**** The rotation is in the opposite direction to that of other planets.

Surface temperatures vary from one planet to another and, depending on the planet, may also change greatly from day to night and from summer to winter.

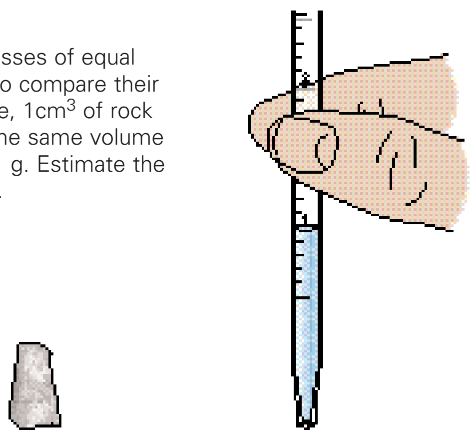
Density, too, differs among the planets **(Figure 1)**.

The planets are made up of different combinations of chemical elements, which is one reason why no two planets are the same. However, scientists have determined that throughout the solar system there are four common elements. These are hydrogen, helium, oxygen, and carbon. Hydrogen and helium are light gases at ordinary pressures. They are found under high pressure on the Sun and the four largest planets. Oxygen is a gas that is needed to support life. Carbon occurs in diamond, coal, and all living things—as far as we know!

Finally, the gravitational field strength or surface gravity of each planet is different. If you jumped up and down on different planets, you would be pulled down with different forces: sometimes more than on Earth, sometimes less.

Figure 1

We can compare the masses of equal volumes of substances to compare their densities. In this example, 1cm^3 of rock has a mass of 3 g, and the same volume of water has a mass of 1 g. Estimate the average density of Earth.



Understanding Concepts

1. **(a)** Name two planets that scientists think have no atmosphere.

(b) Could the same reasons be used to explain the lack of atmosphere on both planets? Explain.

2. Consider all the information in the table.

(a) Which planets appear to be most similar to Earth? Explain.

(b) Which planets could be grouped as those that are least similar to Earth? Why?

(c) Which planet seems to fit into a category by itself?

3. Which planets have densities much lower than Earth's? What can you conclude about these planets?

4. Would the atmospheres on the four largest planets support Earth-type life forms? Explain.

5. Create a mnemonic sentence to help you remember, in order, the names of the planets. (One student started with "My Very Elegant Mother . . . ")

Exploring

6. (7B) Would it be possible to plot a graph of "time for one revolution around the Sun" against "distance from the Sun" for all the planets? Try it. What did you discover?

Challenge

Which planet would be suitable for possible colonization? Give reasons for your choice. How will planet conditions need to be considered in the design of your space colony?

A Model of the Solar System

When you paint a realistic scene that has trees, buildings, and other objects, do you draw each object life-size? Of course not—you must scale down the sizes to fit onto the canvas or paper. Sometimes the objects may be scaled down uniformly. In other words, if you draw a tree 100 times smaller than life-size, you may want to draw a person who is standing beside the tree 100 times smaller than life-size. However, sometimes you may want the scales to be different. For example, if the person is wearing a T-shirt with printing, you may make that printing only 20 times smaller than life-size so it can be read.

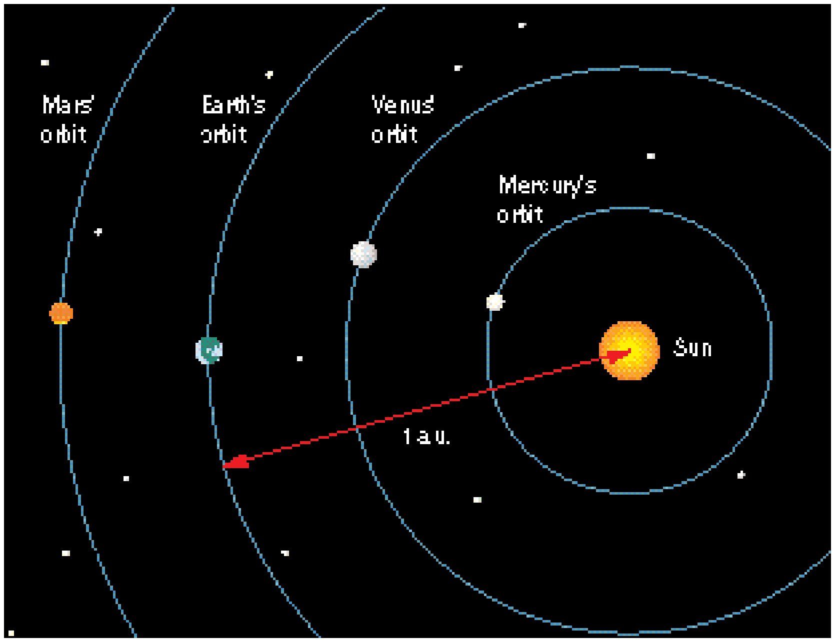


Figure 1

The astronomical unit (a.u.) is about 150 million km. (Note: not drawn to scale.)

In this activity, you will create a model showing the nine known planets of the solar system and their distances from the Sun. You will use two different scales for the model, one for distances and another for the diameters of the planets. Two scales are suggested because the distances are so huge relative to the sizes of the planets.

To compare large distances in the solar system, astronomers sometimes use a distance measurement called the **astronomical unit**, which is the average distance between Earth and the Sun **(Figure 1)**. The astronomical unit (a.u.) is a useful unit because it allows us to compare distances. For example, comet Hyakutake passed 0.1 a.u. from Earth, while the orbit of our nearest planet, Venus, is about 0.3 a.u. from Earth's orbit.

Materials

- thick, coloured paper
- drawing compass or other device to draw circles
- metre stick
- roll of paper tape
- ruler
- scissors
- tape or glue
- calculator

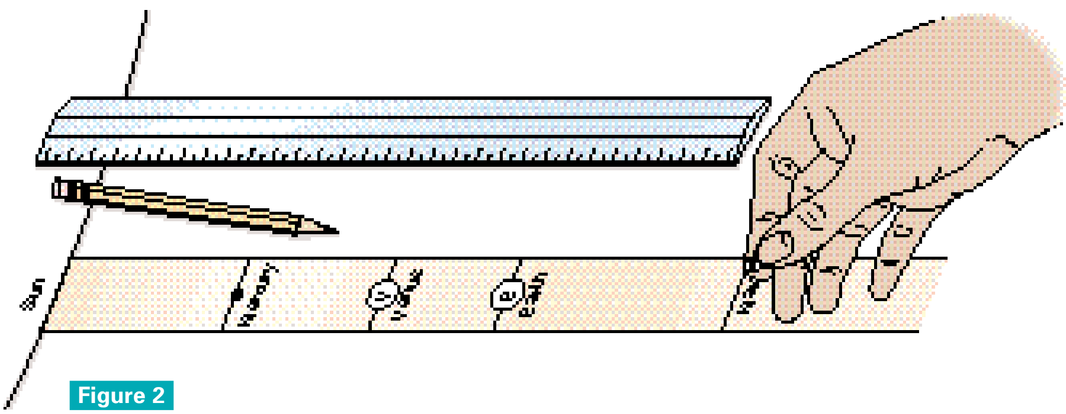


Figure 2

Make sure you label all your circles *before* you cut them out.

Procedure

1 Make up a data table.

(a) Use the following headings: Object; Actual Diameter (km); Scale Diameter (cm); Actual Distance from Sun (km); Actual Distance from Sun (a.u.); Scale Distance from Sun (cm).

(b) In the first column, list the Sun and the nine planets in order of their average distance from the Sun.

(c) Enter the actual diameter of the Sun (1 392 000 km) into your table.

(d) Refer to **Table 1** (page 418) to complete columns 2 and 4 in your table.

(e) Determine the scale diameter of each object, correct to one decimal place, by using the scale 1 cm = 10 000 km. Can you see why Earth should be 1.3 cm? Complete column 3 in your table.

2 Using the data you calculated, draw circles on a sheet of paper to represent the planets. Use a chalkboard compass to draw the Sun. Put the name of each object on the diagram of the object.

3 Convert each planet's actual distance from the Sun from kilometres to a.u.

(a) Write these distances in your table.

4 (7C) Determine the scale distance of each planet from the Sun, correct to the closest centimetre, by using a scale of 20 cm = 1 a.u. (Using this scale, the distance from the Sun to Venus is 14 cm.)

(a) Complete column 6 in your table.

5 Using a metre stick, measure out 8 m of paper tape. From one edge, where the Sun will be located, use the ruler to mark the positions of the nine planets using the data you calculated in step 4 **(Figure 2)**.

6 Use scissors to cut out the objects you drew in step 2. Use tape or glue to attach the planets to the paper tape at the correct locations, as shown in the diagram. Attach the Sun and the rest of the model to a wall, or hang it from the ceiling of your classroom.

Understanding Concepts

1. Some of the planets in your model were very small. If you were to make them 10 times larger, what would happen to the size of the Sun in the model?

2. If you were planning to make a three-dimensional scale model of the solar system, what could you use to represent the planets? Consider their relative sizes. You might start with a ball bearing for the smallest planet.

3. What are the advantages of expressing distances in astronomical units rather than in kilometres?

Exploring

4. Research Pluto's orbit. How is it different from the orbits of other planets? With your new knowledge, would you modify your model in any way?

5. In this activity, the scale used to draw the planets was different from the scale used to measure the distances from the Sun. Design (but don't build!) a model of the solar system in which these scales are the same. Calculate the sizes of the planets and the distances between their orbits for your model.

6. Add Earth's Moon to your model. Its diameter is one-quarter that of Earth, and its distance from Earth is 4.0×10^5 km (400 000 km).

Reflecting

7. Explain why it is impractical to construct a model of the solar system using the same scale for both planet diameters and planet distances.

8. Your model showed the nine planets lined up in a row. What is the advantage of drawing the solar system this way? What is the disadvantage?

Challenge

How would you incorporate this model into a planetarium show? What information does this model provide when considering future space travel for colonization or exploration?

SKILLS HANDBOOK: (7C) Using Math in Science

13.12

Probes to the Planets

If you were an astronaut travelling to a distant planet to found a new colony, you would want to have as much information as possible about your destination. We are already collecting information by sending probes to investigate our solar system. This is safer and cheaper than sending humans to explore distant locations.

A space probe is an unpiloted spacecraft sent to explore parts of the solar system beyond Earth. The probe collects information and transmits it back to Earth. The first space probes, launched in 1959, took close-up photographs showing the first views ever seen of the far side of the Moon. Since then, probes have been sent to every planet in the solar system except Pluto, to the Sun, and even to a few comets and asteroids.

Space probes help us better understand the origins and characteristics of Earth, the solar system, and the universe. For example, learning about the greenhouse effect in the dense atmosphere of Venus will help scientists understand the greenhouse effect on Earth. **Table 1** lists some space probes that have been sent to explore the planets.

An amazingly successful probe is the American *Voyager 2* craft (**Figure 1**), launched in 1977 to study Jupiter, Saturn, Uranus, and Neptune. *Voyager 2* sent back clear images of the planets and their moons, along with detailed information on their atmospheres. It has given scientists a huge quantity of material that will take years to analyze. By the time *Voyager 2* passed Neptune, it had been travelling for 12 years, covering a distance of 4.5×10^7 km (45 million km).

Understanding Concepts

1. Describe the uses or functions of space probes.
2. State reasons why space probes are usually unpiloted.

Making Connections

3. How do space probes help in the advancement of science?

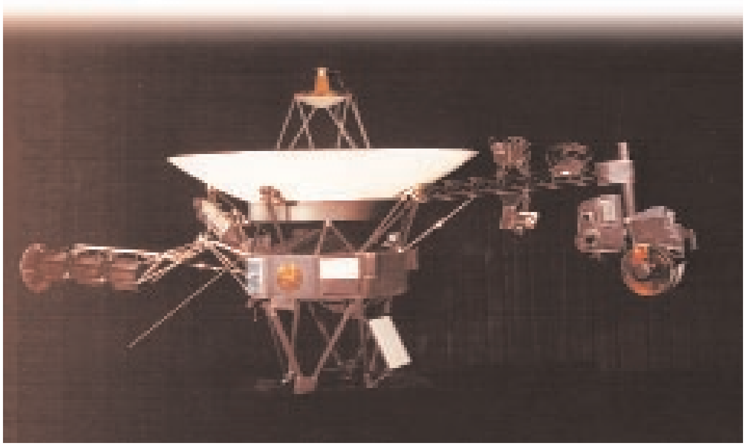
Exploring

4. As the spacecraft *Pathfinder* landed on Mars, it bounced 16 times. Research how probes are designed so they can land safely. Draw some of the designs.

Table 1 Recent and Future Probes to Planets and Moons

Probe Name	Year of Launch	Scheduled Arrival	Details
Magellan	1989	1995	Successfully mapped Venus using radar waves; was deliberately crashed into the planet in 1995
Galileo	1989	1995	Flew past asteroids in 1991–92; explored Jupiter and its moons starting in 1995; found that winds on Jupiter extend to depths of thousands of kilometres
Mars Global Surveyor/ Pathfinder	1996	1997	Two probes, an orbiter and a lander, sent to study Mars; *Pathfinder* landed on Mars and sent a robotic rover *(Sojourner)* to explore the surface.
Cassini	1997	2004	U.S.–European probe studying Saturn and its largest moon, Titan; expected to operate to 2008
Mars Surveyor '98	1998–99	1999	Two small spacecraft—the *Climate Orbiter*, launched in 1998, and the *Polar Lander*, launched in 1999—will study the evolution of the climate of Mars and search for water in its soil.

Figure 1
Once *Voyager 2* leaves our solar system, it will take about 20 000 years to travel as far as our next nearest star.



13.13 Investigation

SKILLS MENU
- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

The Speed of Planets

Have you ever played "crack the whip" on ice? In this game, skaters link arms and move in circles around a central skater. The skater farthest from the centre of the circle is whipped around at the highest speed. Does the same idea apply to the speeds of the planets around the Sun? Find out for yourself as you explore the connections between two or more characteristics of the planets. Look at the first four rows of **Table 1** on page 418. Which characteristics, or variables, may be associated? How will you investigate the relationship? Decide which question to investigate and how to answer it, then carry out your plans.

Question

1 Formulate your own question about the speeds of the planets. (2A)

Hypothesis

2 Write a hypothesis, giving reasons.

Materials

3 List materials, including reference materials, that you will require.

Experimental Design

4 Plan your own procedure, including the steps you will take to search for answers to the question. Include ideas about how you intend to communicate what you discover to others. Before you go on, ask your teacher to approve your steps.

Procedure

5 Carry out your investigation as planned, making notes as you proceed. If you change the procedure, record the changes.

Analysis and Communication

6 Analyze and write a summary of your results by answering the following questions:

(a) What relationship, if any, did you discover?

(b) Did your results support your hypothesis? Explain.

Reflecting

1. Asking questions that can be tested is the key to valid experimenting. How did your question help direct your investigation? What suggestions would you give to others to consider when they are thinking of questions to investigate?
2. Explain your choice of variables for this investigation. How might your results be affected if you choose other variables?

Challenge

What physical model could you design for the planetarium challenge that would represent the relationship under investigation?

A Closer Look at the Planets

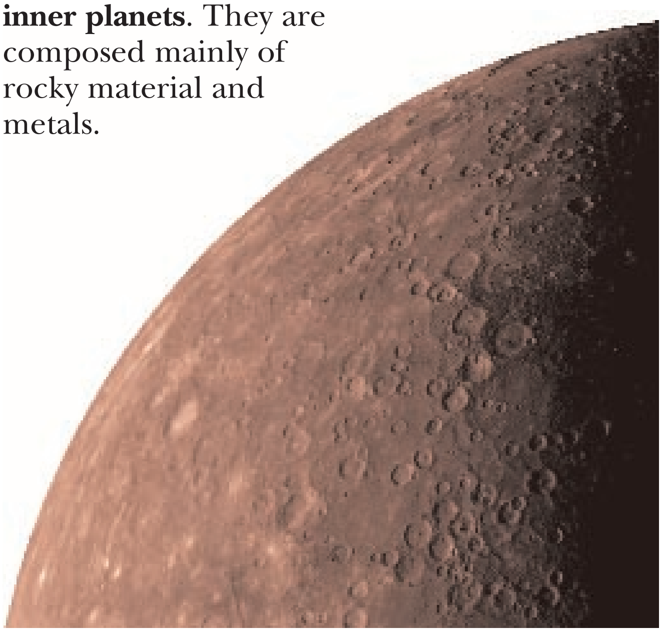
Space probes have flown close to all the planets except Pluto, sending back images that allow us to see details of those planets for the first time.

We can group the planets into two main categories, those that are nearest to the Sun and those that are much farther from the Sun. Let's go on a photo journey to look at the planets in order.

> **Did You Know?**
>
> Aerobots are space probe balloons used to explore planets, such as Venus, that have an atmosphere. Scientists are designing a balloon that may be used to float above the surface of Mars and to take photographs. This will be a technological challenge because of the low density of Mars' atmosphere.

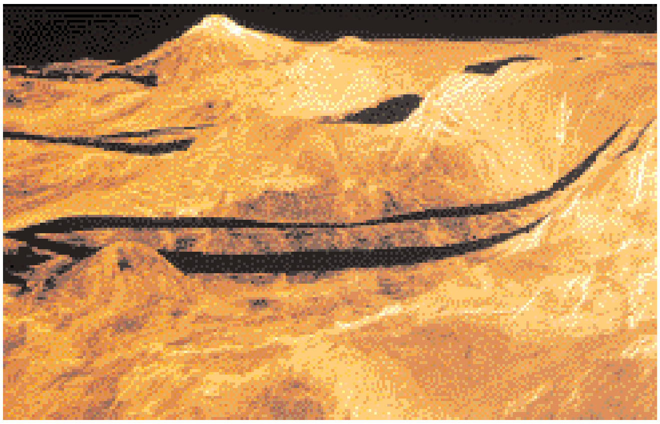
The Inner Planets

The four planets closest to the Sun are Mercury, Venus, Earth, and Mars. They are all small, and their densities are about 5 g/cm^3, which is roughly the density of rocks. Because these planets resemble Earth, they are called the **terrestrial planets** (from the Latin for Earth: *terra*). These planets are also known as the **inner planets**. They are composed mainly of rocky material and metals.



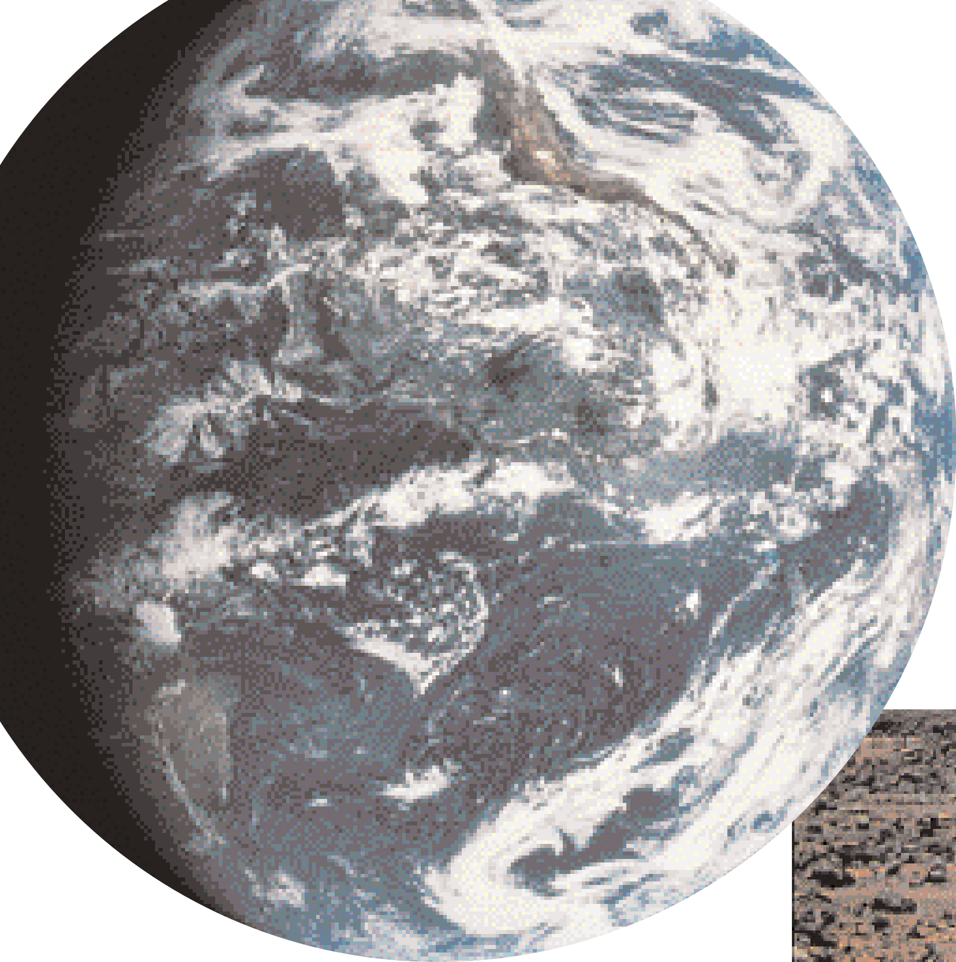
Mercury

- Mercury, the closest planet to the Sun, receives sunlight about 10 times brighter than Earth does, giving daytime temperatures over 400°C. However, it has no atmosphere to trap heat, so nighttime temperatures fall to –180°C .
- Craters were caused by chunks of rock colliding with Mercury.
- Mercury might be seen only a few times during the year just before sunrise or after sunset.
- Because Mercury is so close to the Sun, it is rarely visible in our night sky.



Venus

- This view of the surface of Venus shows a volcano that is 1.7 km high. Lava from the volcano has flowed hundreds of kilometres across the surface.
- After the Sun and Moon, Venus is the brightest object we can see in the sky because of its closeness to Earth and because its thick atmosphere reflects sunlight.
- The atmosphere is made mainly of carbon dioxide. This gas acts like the glass of a greenhouse, keeping the surface temperatures high enough to melt lead.
- Exploring the surface of Venus is not easy. This image was provided by the space probe *Magellan*. It had special radar cameras that could penetrate the thick atmosphere.



Earth

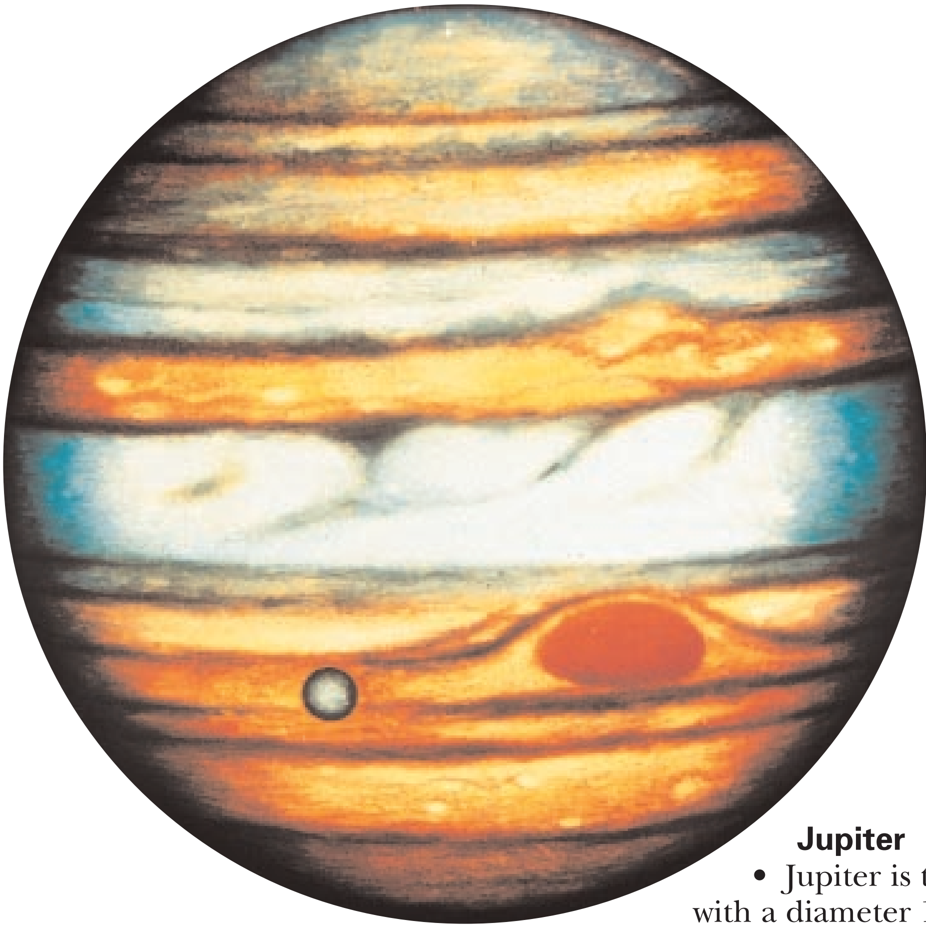
- From our point of view, the conditions on Earth are ideally suited for life, but we should remember that it is actually the other way around: life is ideally suited for Earth.
- Earth's unique atmosphere contains mostly nitrogen, oxygen, and water vapour. There is also a small amount of ozone in the atmosphere which filters some of the damaging radiation from the Sun, but lets enough through to support life. It also keeps the temperatures relatively constant between day and night, although there is a wide variation of temperatures between the poles and the equator (–85°C to about 65°C).
- Vast amounts of liquid water in the lakes, rivers, and oceans cover over 70% of the planet's surface.
- Much of the land surface has soil, resulting from erosion and organic material, covering the solid rock. This is an ideal medium for the growth of land plants.
- There are some active volcanoes and earthquakes changing the face of the planet, but it is mostly considered to be stable.

Mars

- Mars is one of the brighter objects in the sky and is sometimes called the red planet because of the reddish colour of its rusty soil.
- In 1997 the space probe *Pathfinder* landed on Mars, carrying a small vehicle called the *Sojourner* rover, which drove around exploring, sending images back to Earth, and collecting all kinds of data.
- Although it is very dry and barren now, there is evidence that Mars once had volcanoes, glaciers, and floods of water. Scientists have been especially interested in the possibility of some form of life there, and they have studied Mars more closely than any other planet, except Earth. No signs of life have yet been found, however.

The Outer Planets

Lying in the vast regions of the solar system beyond the four inner planets are the remaining five planets. They are called the **outer planets**. Four of these, Jupiter, Saturn, Uranus, and Neptune, are large, and their atmospheres consist mainly of the gases hydrogen and helium, which have low densities. For this reason, these four planets are called the **gas giants**. The gas giants appear to lack solid surfaces. Deep inside the atmosphere of these giant planets, the gases may become more dense, eventually becoming liquids and solids. The cores of these planets may contain metals, as those of the inner planets do. The outermost planet, Pluto, is unique among the outer planets.

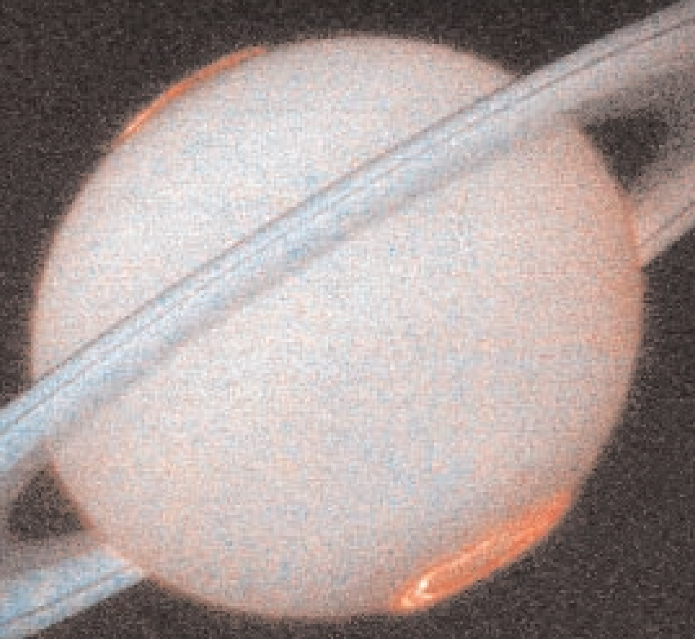


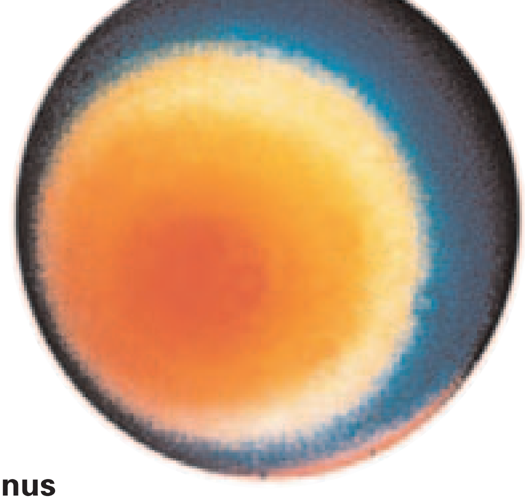
Did You Know

A space probe launched toward Neptune now would take about 30 years to get there. Why, then, did *Voyager 2* take only 12 years to travel the distance? The reason is that Jupiter, Saturn, Uranus, and Neptune were lined up in a way that allowed their forces of gravity to increase the probe's speed. This alignment occurs only once every 176 years!

Jupiter

- Jupiter is the largest of all the planets: with a diameter 11 times that of Earth it has a greater mass than all the other planets combined. Its large size, plus the large amount of light reflected by its clouds, makes Jupiter very bright in the night sky.
- Jupiter's most interesting features are its coloured bands and the Great Red Spot, a huge hurricane fed by constant high winds. Larger than the size of two Earths, this hurricane already existed hundreds of years ago, when people first looked at Jupiter through telescopes, and it still shows no sign of dying away.
- Jupiter and its 16-or-so moons have been observed from close range by several space probes: *Pioneers 10* and *11*, *Voyagers 1* and *2*, and *Galileo*. You might even be able to see four of these moons—Io, Europa, Ganymede, and Callisto—through binoculars. What you can't see from Earth, however, are Jupiter's orbiting rings of rocks.



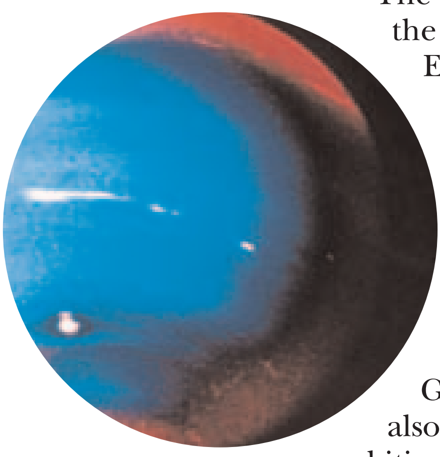


Saturn

- Saturn, at about five-sixths the diameter of Jupiter, is the second largest planet in the solar system. The least dense of all the planets, it is possible that it has no solid core.
- Saturn's atmosphere is cloudy and, because of its quick rotation, windy. Saturn is farther from the Sun than Jupiter, so its average temperature is lower: about –180°C.
- For hundreds of years, people thought that Saturn was the only planet with rings. Detailed images sent by *Pioneer 11* and the two *Voyager* space probes showed that there are actually over 1000 separate rings. Astronomers are not certain whether the rings formed at the same time as the planet or are the crumbled remains of one of Saturn's many moons or some other object that came too close to the planet.

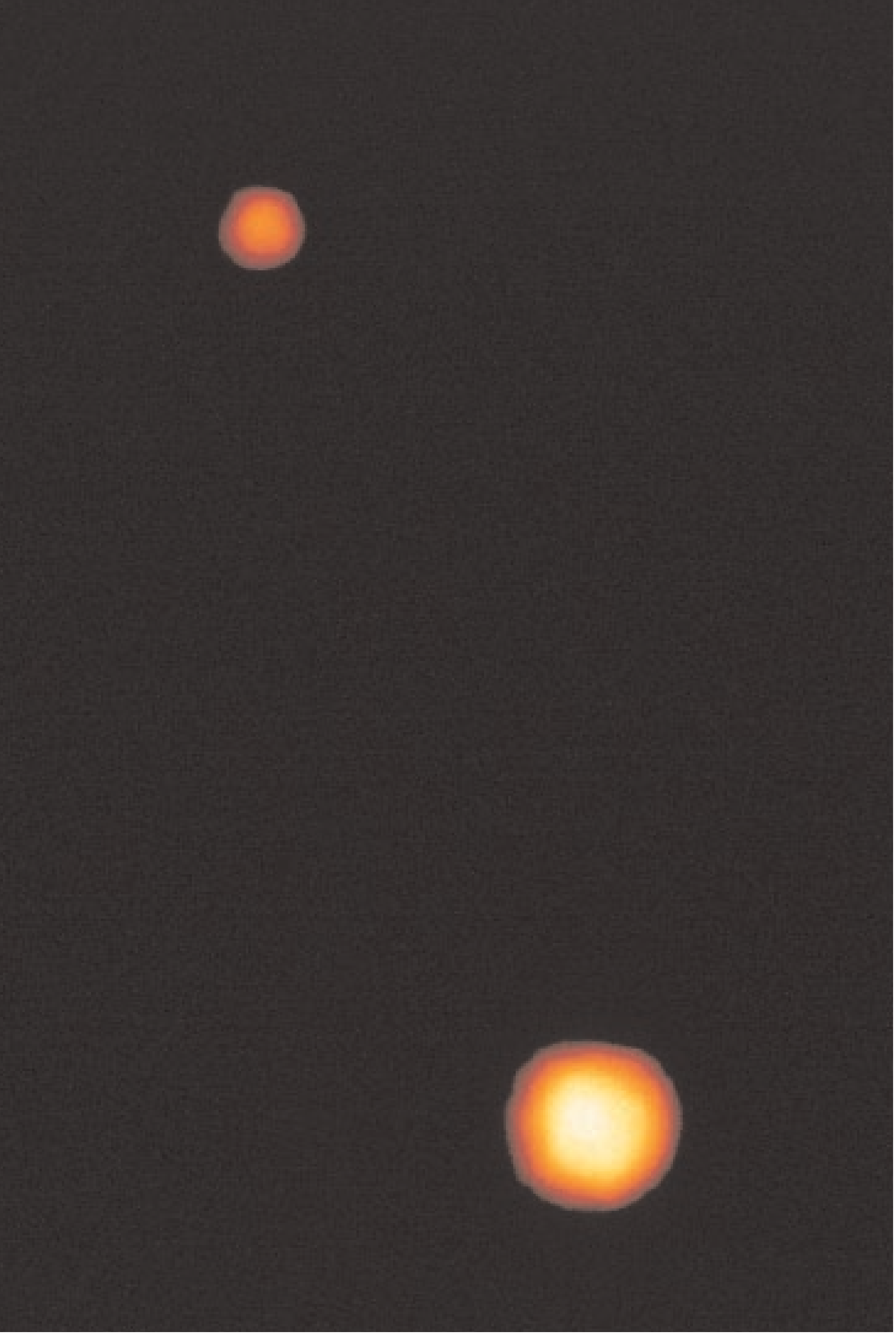
Uranus

- Although Uranus's diameter is almost four times that of Earth, it is so far away that it looks like a faint star. It was actually thought to be a star until its motion was discovered in 1781.
- Astronomers gathered considerable data about Uranus when *Voyager 2* passed near it in 1986.
- Uranus is unusual because its axis of rotation is in nearly the same plane as its orbit. This means that Uranus rotates on its side; the orange patch in the computer-enhanced photograph is a polar hood over the south pole.
- The atmosphere of Uranus is made up mostly of hydrogen, with some helium and methane. It has winds that blow up to about 500 km/h.



Neptune

- The story of the discovery of Neptune, the second farthest planet from the Sun, is one of great scientific achievement. Neptune is so far from Earth that it is barely visible, even through powerful telescopes. After 19th-century scientists established that Uranus was a planet and not a star, they studied its orbit and discovered that the orbit was not a smooth circular path. They hypothesized that some other object must be "tugging" on Uranus, causing its uneven orbit. Using detailed calculations, they predicted where this hidden object must be, searched, and discovered the "missing" planet in 1846.
- In 1989, computer-enhanced images from *Voyager 2* revealed that Neptune has bright blue and white clouds, and a dark region—the Great Dark Spot—that appears to be the centre of a storm. *Voyager 2* also uncovered the existence of at least eight moons and some thin rings orbiting Neptune.



Pluto

- Pluto is an unusual planet because it is not a gas giant and it does not seem to be terrestrial. It was discovered in 1930 after a painstaking search.
- Pluto is so far away that it takes 248 years to orbit the Sun. Although astronomers haven't yet observed a complete orbit, they have seen enough to detect that Pluto's orbit is elliptical and not quite centred on the Sun. Pluto actually passed within the orbit of Neptune, making it the eighth planet from the Sun, from January 1979 until February 1999. Pluto's unusual orbit has led some astronomers to suggest that it may have been a moon of Neptune at one time.
- Images taken by the Hubble Space Telescope have given us our best information yet about tiny, cold, distant Pluto and its moon, Charon.

Understanding Concepts

1. Why are the four closest planets to the Sun called the "terrestrial planets"?
2. Describe two features that make Earth unique among the planets, and two that make it similar to other planets.
3. Why is Jupiter easy to see in the night sky (when viewing conditions are right)?
4. There may be other groups of planets similar to our solar system, but they are very difficult to detect. Why?
5. How would the tilt of Uranus affect its seasons?

Making Connections

6. What are some features of a roving robot you would design for exploration on Mars?
7. List five or six ways that humans have had an impact on Earth and mention how each has had positive and negative results on life on Earth.

Exploring

8. Research the orbits of Mercury and Earth around the Sun. Draw a diagram to illustrate them and use it to explain why Mercury is so difficult to see from Earth.

Reflecting

9. List the steps that were followed in discovering Neptune. How do these steps relate to the process of scientific discovery?

Prize-Winning Astronomer

Mary Lou Whitehorne is a stargazer who, within eight years, captured Canada's highest award for an amateur astronomer—the Chant Medal. How did she do it, and why?

As a Girl Guide in Bedford, Nova Scotia, Whitehorne was interested in the sky but, with no expert to talk to her and no local library, her interest waned. After high school, she graduated in medical laboratory technology and pathology, but left her medical career to raise a family with her husband, Lloyd.

She went back to school, at age 31, to study at the Astronomy Department of St. Mary's University. She undertook a three-year study of a rare type of star known as a B-emission star. "B-stars" vary in brightness, so she decided to investigate the light they emit. She spent many hours examining their spectra through a telescope to investigate their atomic composition. "It is challenging raising two kids while observing the stars every clear night past midnight," she says, but she did it. She published two scientific papers, winning the 1993 Chant medal for her research efforts.

She has since completed ground school and flight training and has been awarded her Private Pilot Licence. She has also helped to establish a hands-on astronomy program for schools in Nova Scotia. In her spare time, she opened a resource centre for the Canadian Space Agency in the Atlantic region.

> "It's Terry Dickinson's fault. In 1985, I saw a hokey little star chart in his newspaper column. In it, he said that you could see four moons of Jupiter all aligned on one side–with binoculars. That was all it took and I was hooked."

Exploring (3A)

1. Find out if there are any introductory astronomy courses or programs in your area. Attend a stargazing party, if you can, and learn about the sky from an expert.
2. A beginner's telescope is usually priced at $350 or less. Most astronomers will tell you that it is a big mistake to buy this type of instrument to explore the sky. Why?
3. Search the Internet for astronomical societies or amateur observing groups and write a brief summary of their activities.

Other Objects in the Solar System

About 60 million years ago, the dinosaurs that had roamed on Earth for millions of years died out in a fairly short time, along with many other species. What could have caused this extinction? Scientists have found evidence that a fast-moving object from outer space crashed into Earth, sending material flying into the atmosphere. This material reduced the amount of sunlight reaching Earth's surface, causing the climate to change and numerous life forms to die out.

As scientists study more about these objects from space, they hope to find clues about how life may have formed on Earth.

Did You Know

As of 1997, astronomers had observed 15 moons orbiting Uranus. Then Canadian astronomers discovered two more moons, bringing the count to 17.

Planetary Moons

Large natural objects that revolve around planets are called **satellites**, or moons. Several planets have more than one moon, but the chunks of rock that make up the rings of the gas giants are far too small to be considered moons.

Probably the most famous satellite of any planet is Earth's Moon, which has a diameter about one-quarter that of Earth. Six visits to the surface of the Moon by humans from 1969 to 1972 provided much new information **(Figure 1)**. The Moon has no atmosphere, and its surface is filled with hills and valleys as well as craters caused by the impact of large and small objects from space.

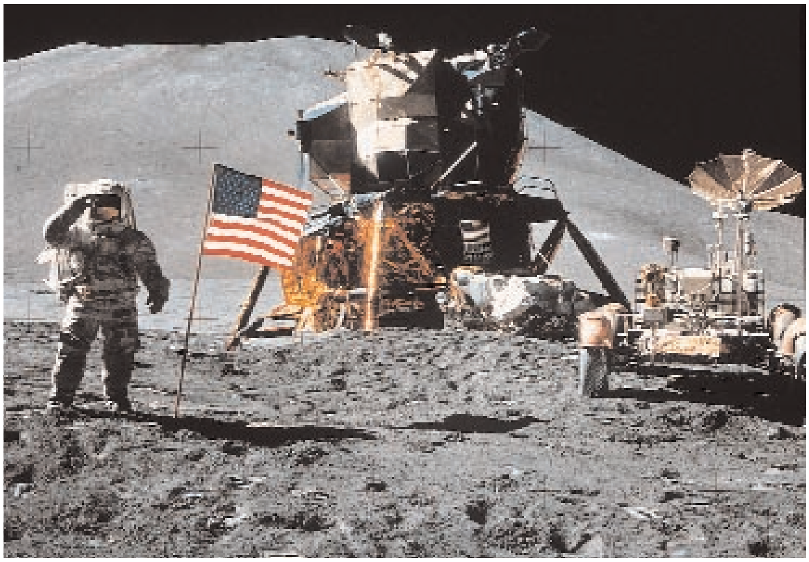


Figure 1
The *Apollo* astronauts brought moon rocks to Earth for detailed study and collected data on the moon's soil, surface conditions, and moonquakes.

The moons of the other planets were discovered after the invention of the telescope. In 1610 Galileo Galilei looked at Jupiter through his telescope and became the first person to see four of Jupiter's moons.

Although humans have not yet been to other satellite moons besides our own, space probes have investigated several at close range, including the two small moons of Mars and many of the largest moons of Jupiter and Saturn.

What has surprised astronomers most about moons is the great differences in their sizes and surfaces, as **Figure 2** shows.

Table 1 lists the number of known moons revolving around the planets of the solar system. Only the numbers of moons revolving around the four terrestrial planets are known for certain. Future space probes may reveal more moons in our solar system.

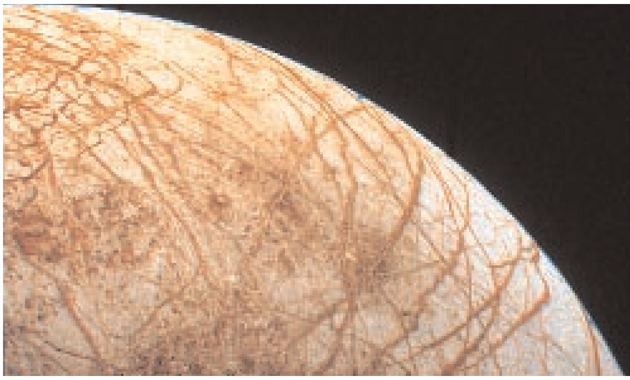
Table 1

Planetary Moon Count (1998)

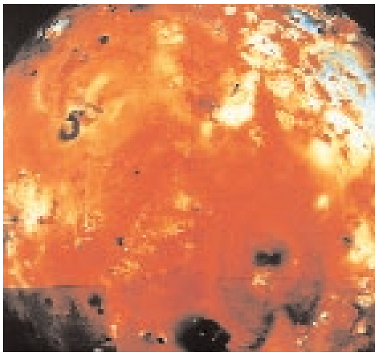
Planet	Number of known moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	16
Saturn	18
Uranus	17
Neptune	8
Pluto	1

Studying the many planetary moons in the solar system helps us understand more about the origin and evolution of the solar system. But we may find other uses for these moons in the future. The moons contain huge amounts of useful minerals that humans may mine one day and use for construction on Earth or on other planets. Who owns the moons and the minerals they contain? Who will hold mining rights? Do humans have the right to affect the environments of other places, when we have shown little regard for Earth's environment? These controversial questions will stimulate much debate in the years to come.

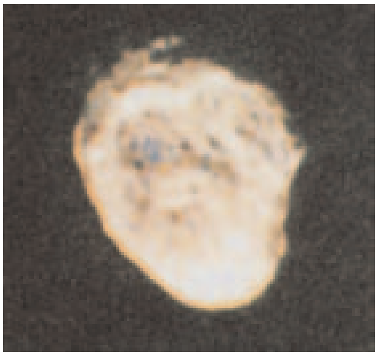
Figure 2



a Jupiter's moon Europa has an icy surface with very few craters and is nearly as big as Earth's Moon.



b Io, the closest moon to Jupiter, is the only moon in our solar system known to have active volcanoes, more violent than any on Earth.



c Saturn's moon Hyperion is only 360 km across and has an irregular shape, possibly as a result of repeated collisions with large space rocks.

Asteroids

Refer to the model of the solar system on page 401. There is a large gap in the solar system, between the orbits of Mars and Jupiter. In that space is a ring around the Sun, made up of thousands of small rocky objects called **asteroids**. This ring of asteroids is called the **asteroid belt** and has been explored by several probes. The word asteroid comes from the Greek word *astron* meaning "starlike," but a better name would be "minor planet." Scientists think that the asteroids might have formed into a planet if the gravitational force of the large planet, Jupiter, had not been so strong.

There are also asteroids sharing Jupiter's orbit, while others travel in paths that may take them closer to the Sun or Earth. In 1937 an asteroid named Hermes came within 800 000 km of Earth, only about twice the distance from Earth to the Moon. **Figure 3** shows the orbits of some asteroids and their names.

Like the planetary moons, asteroids are rich in minerals, which humans may someday mine. The largest asteroid is only about 1000 km in diameter, so it has low gravity. This means that a spacecraft carrying mined minerals would require much less energy to blast off from an asteroid than from Earth, Mars, or even our own Moon.

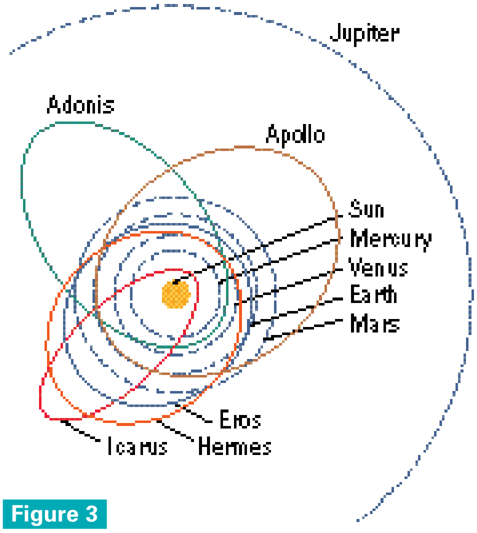


Figure 3
Orbits of several asteroids (Note: not drawn to scale.)

Meteors and Meteorites

A **meteoroid** is a lump of rock or metal that is trapped by Earth's gravity and pulled down through Earth's atmosphere. As it falls, it rubs against the molecules of the air. This rubbing, called friction, causes the meteoroid to become hot and vaporize, and the air to glow. This produces a bright streak of light across the sky, called a **meteor**, that you can see at night.

Where do meteoroids come from? The largest are probably asteroids in orbits that cross Earth's orbit. The millions of tiny meteoroids that produce spectacular displays called meteor showers probably come from the debris left behind by comets. Most meteoroids vaporize completely before they reach Earth's surface. If the object is large enough to hit the ground before totally vaporizing, it is called a **meteorite**. If a large meteorite hits Earth's surface, it can produce a crater. The best-preserved meteorite crater in North America is the Barringer Crater near Winslow, Arizona (**Figure 4**), but there are also many in Canada.

Try This: Meteor Showers

Have you heard of shooting stars or falling stars? They are not stars at all: they are meteors. If you view the sky on a clear night, you might see a meteor. View the sky during a meteor shower and your chances of seeing one become very high. The three most active meteor showers are the Perseid shower (August 12), the Geminid shower (December 14), and the Quadrantid shower (January 3 or 4).

Figure 4
Evidence gathered from local rocks suggests that the Barringer Crater was formed 20 000 to 30 000 years ago by a large meteorite. The crater is 1.2 km in diameter and 120 m deep. Why are most craters this shape?

Comets

One evening an amateur astronomer from Japan, Yuji Hyakutake, was viewing the night sky through a powerful pair of binoculars (20 × 50). In an area of the sky he had examined before, he noticed an object he had never seen. Like any thorough amateur astronomer, he recorded what he saw, then he reported it to professional astronomers. To everyone's excitement, Hyakutake had discovered a **comet**, which is a chunk of frozen matter that travels in a very long orbit around the Sun (**Figure 5**). Because Hyakutake had reported finding the comet, it was named after him.

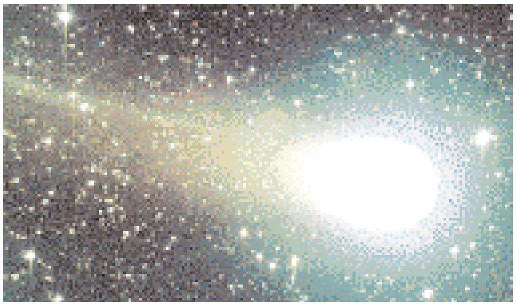


Figure 5
Comet Hyakutake, discovered in 1996, was the brightest comet seen in 20 years. It passed within 1.5×10^7 km of Earth—only a tenth of the distance from Earth to the Sun.

One of the most interesting and exciting things you could see in the night sky is a comet with a tail that is millions of kilometres long. A few comets have been so bright that they were visible even in daylight.

During most of its elliptical orbit around the Sun, a comet remains far out in the solar system. When it approaches the Sun, however, the comet is warmed by solar radiation and the frozen substances become gases. As the comet travels closer to the Sun, these gases are pushed outward by solar wind and radiation, forming a bright, glowing tail that may be over 10^8 km long. The glowing tail may be seen for several months as the comet travels near the Sun.

Many comets have regular periods of revolution around the Sun. This allows us to predict when they will be close enough to the Sun to be seen. For example, a regular visitor is Halley's comet, last seen in 1986. It has a period of 76 years.

Exploring the Minor Bodies

Think of a chocolate bar that has many mixed ingredients covered with chocolate. In order to figure out how the bar was made, you would start by finding out the ingredients. Scientists go through a similar process when they try to figure out what formed Earth and other planets. Scientists think that the ingredients of the planets and moons were objects similar to asteroids and comets—the minor bodies of the solar system. Unlike Earth, many of the minor bodies have changed little since the birth of the solar system. This is why scientists send probes to the minor bodies to learn more about them, and perhaps learn more about the origin of the solar system.

A probe called *Deep Space 1*, launched in 1998, is the first of a new type of probe, sent to explore minor bodies. This light-weight probe was sent to study an asteroid about 1.9×10^8 km away. The probe is unique because its main source of energy uses ions (charged particles) of xenon and mercury gases. These ions escape at extremely high speeds from the rear of the vehicle, causing a forward thrust on the vehicle. The amount of fuel needed is only about 10% of what a conventional rocket uses. Another feature of this probe is that, when it gets closer to the asteroid it is chasing, it will use an on-board computer to decide on its final approach. This form of artificial intelligence is being used more and more for space exploration (**Figure 6**).

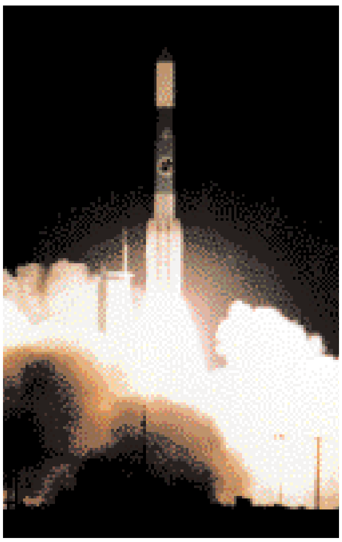


Figure 6
Deep Space 1

Understanding Concepts

1. **(a)** What is an asteroid?
   (b) Where is the asteroid belt?
2. **(a)** Explain the difference between a meteoroid and a meteorite.
   (b) Why are meteorites less common than meteors?
3. Using a labelled diagram, describe what causes the glowing tails of comets.
4. Both comets and planets orbit the Sun. How do their orbits differ?
5. When will Halley's comet next be close enough to the Sun to be seen?

Making Connections

6. Describe what might happen if a giant meteorite crashed into Earth's surface (a) on land (b) on water. On a map of the world, mark the spots where a meteorite would have the least impact on human life.

Exploring

7. The names of many astronomical objects may sound romantic or old-fashioned to us: many of them were named thousands of years ago. However, some recently discovered objects are given exotic names, too.
   (a) What are the planets of our solar system named after?
   (b) Find out what the features on the surface of Venus are named after.
8. One theory suggests that the extinction of dinosaurs may have been caused by the collision of a small asteroid or comet. Investigate this theory. Do you agree or disagree?
9. Of all the planetary moons in our solar system, which one would you be most interested in visiting on a scientific expedition? Research and describe the special features of this moon, and explain what you would try to discover about it while you were there.
10. Chart the names and dates of meteor showers, as well as the point in the sky from which the meteor appears to orginate.

Reflecting

11. Space exploration is costly. Do you think sending probes to explore the minor bodies is justified? Give reasons to support your opinion.

Chapter 13 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe and compare constellations. (13.1, 13.3, 13.4, 13.7, 13.8)
- Investigate the motions and characteristics of objects visible in the sky and organize, record, and communicate your results. (13.2, 13.4, 13.5, 13.7, 13.8, 13.11, 13.13)
- Analyze data and use them to predict future observations, such as when to see a seasonal constellation or the return of a comet. (13.2, 13.7, 13.8, 13.13)
- Plan ways to model answers to questions about the motion of objects in the sky, and communicate results. (13.2, 13.8, 13.11, 13.13)
- Describe and compare the properties and motions of the objects in the solar system. (13.1, 13.2, 13.7, 13.8, 13.11, 13.13, 13.14, 13.15)
- Formulate and research questions related to sky-watching and the solar system, and communicate results. (all sections)
- Describe and explain how data from space probes contribute to our knowledge of the solar system. (13.12, 13.15)
- Describe different ways in which various cultures have understood the universe (13.6)
- Evaluate the impact of light pollution on the work of astronomers. (13.9)
- Identify careers related to the exploration of space. (Career Profile)

KEY TERMS

asteroid	orbital period
asteroid belt	outer planet
astronomical unit	planet
astronomy	revolution
axis	rotation
comet	satellite
constellation	solar system
gas giant	star
inner planet	Sun
light pollution	terrestrial planet
meteorite	universe
meteoroid	zodiac constellation
nonluminous	
orbit	

Reflecting

- "Observation of the stars has affected many human beliefs and activities, including navigation, calendar-making, and the creation of myths." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the word "Sun."
2. Each of the following descriptions fits one of the planets in the solar system. Name the planet described by each sentence.
   (a) It was discovered in 1846 after careful observations.
   (b) It has more mass than all the other planets combined.
   (c) It has surface temperatures ranging from –180°C to 400°C.
   (d) It has an atmosphere containing oxygen.
   (e) It is neither a gas giant nor a terrestrial planet.
   (f) It has over 1000 rings around it.
   (g) It appears reddish in colour.
   (h) It has a very warm surface caused by its thick atmosphere.
   (i) It rotates on its side.
3. Why does a meteor appear as a streak of light in the sky?

4. (a) Describe Earth's position among the nine planets of the solar system.
   (b) Describe several features of Earth that make it unique in the solar system.

5. Choose one planet and name three similarities and three differences between it and Earth.

6. Why are some comets seen much more often than others?

7. (a) State one constellation that you can see best during each of the four seasons.
   (b) Why can you see some constellations only during certain seasons?

8. Mercury is much closer to the Sun than Earth is, yet at night its surface temperature can fall much lower than the lowest surface temperature on Earth. Why do you think this happens?

9. (a) Why do you think craters caused by meteorites are rare on Earth?
   (b) Why do you think there are many meteorite craters on a planet such as Mercury?

10. Would the asteroid belt be dangerous to travel through in a spacecraft? Explain why or why not.

11. Describe a demonstration you could perform with other students to illustrate both revolution and rotation. Try your ideas.

12. Look back to Table 1 on page 418. On which planets would you weigh more than you do on Earth? On which would you weigh less?

Applying Skills

13. If you wanted to see the planets, where would you look in the night sky? Explain your answer.

14. (a) Use your hands to measure the angular sizes of at least five different objects outdoors. Create a table for your measurements, and draw conclusions about the relative sizes of the objects.
    (b) If the objects you investigated had been constellations, would you have been able to draw similar conclusions about their relative sizes?

15. Why do the planets all have different surface temperatures? Interpret the information in Table 1 on page 418 to find reasons for the differences.

16. Describe how you would use "pointer stars" to locate each of the following stars or constellations in the night sky:
    (a) Polaris
    (b) Cassiopeia
    (c) Sirius
    (d) Arcturus
    (e) Regulus

17. Many books are available on how to build your own telescope. Obtain one or two such references and write plans to build such an instrument. If possible, begin your project soon so you can use the telescope to view the planets.

Making Connections

18. What are some benefits that scientists would achieve by sending space probes to objects in outer space?

19. Before humans are sent to explore other planets, robots are sent to study areas of the planet.
    (a) Describe two advantages of using robots rather than humans for such exploration.
    (b) Describe two advantages of sending humans rather than robots.

20. The table below shows a total of 63 known planetary moons in the solar system in 1998. If you checked other reference books published in earlier years, you would find the number of moons listed as follows:

Year of publication	Number of known moons
1969	28
1984	44
1987	53
1991	60
1998	63

    (a) Why has the number of known moons changed so greatly in such a short period of time?
    (b) Do you think the number of moons will change as much in the next 25 years or so? Explain why or why not.

21. (a) Describe some of the problems that humans might face as they try to set up a settlement on Mars.
    (b) Suggest ways to overcome each of the major problems you listed in (a). Explain your answer in each case.