8 The solar system formed 5 billion years ago, in the same way other star-and-planet systems in the universe formed.

Silhouetted against a red background of dust and gases is the distinctive Horsehead Nebula, surrounded by brilliant stars. Nebulae are often referred to as stellar nurseries because it is out of the dust and gases that new stars form.

Skills You Will Use

In this chapter, you will:

- use star charts to determine the location, appearance, and motion of well-known stars visible in the night sky
- plan and conduct a simulation to show the interrelationship between a star's brightness and its distance from Earth
- compare and contrast star size and spectral patterns
- gather and record data to calculate the diameter of the Sun
- compare the relative sizes of the major components of the solar system, using an appropriate format

Concepts You Will Learn

In this chapter, you will:

- describe the formation and life cycle of stars, including the Sun
- describe and give evidence for the generally accepted theory of the formation of the solar system
- describe the characteristics of the major components of the solar system, including the Sun, the planets, and the Moon
- explain the causes of astronomical phenomena such as the aurora borealis, solar eclipses, and phases of the Moon

Why It Is Important

Studying the formation and life cycles of stars helps us understand what we and everything around us are made of. Studying the motions of Earth and how the Moon and the Sun influence Earth helps us understand why, for example, solar and lunar eclipses occur, comets sometimes streak through the sky, and tides rise and fall.

Before Reading

Thinking Literacy

Determining Importance

When information seems far beyond your experiences, you must determine its importance to you. Skim the bulleted items on this page and the next. Then, write two statements about how the solar system and the formation of stars are important to you.

Key Terms

• aurora borealis • constellation • lunar eclipse • planet
• protostar • revolution • rotation • solar eclipse
• solar wind

8.1 Stars

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

- A star is a huge ball of hot gas, or plasma. Nuclear reactions in its core turn matter into energy.
- A star forms inside a nebula as gravity pulls dust and gas together, creating a spinning, contracting disk of material in which nuclear fusion begins.
- Stars have life cycles during which they form and then evolve in one of three main ways.
- Eventually, most stars cool down and slowly grow cold and dark. Some, however, expand into giants before then cooling down slowly or exploding as a supernova.

Figure 8.1 The Big Dipper seen at dusk over Lake Ontario

Stars: The View from Earth

If you have ever spent time looking up at the sky on a clear night, you have probably noticed that some stars look as though they are grouped together into a distinct pattern. Perhaps the best-known star pattern in the northern hemisphere is the Big Dipper (Figure 8.1). Different cultures around the world refer to this collection of seven stars by other names, such as the Plough, the Ladle, and the Great Cart.

The Big Dipper is part of a larger star pattern known as Ursa Major, which is Latin for Great Bear (Figure 8.2). Ursa Major is an example of a constellation. A **constellation** is a group of stars that, from Earth, resembles a recognizable form. Astronomers have officially listed a total of 88 constellations. Examples, along with Ursa Major, include Cassiopeia, Orion, Pegasus, Sagittarius, and Ursa Minor. Smaller recognizable star patterns within a larger constellation are known as **asterisms**. The Big Dipper is an asterism. Star patterns like these are just one kind of **astronomical phenomenon**, a term that refers to any observable occurrence relating to astronomy.

WORDS MATTER

"Constellation" is derived from the Latin words *con*, meaning with or together, and *stella*, meaning stars. "Asterism" is from the Greek word *aster*, meaning star.

It is easy to think that all the stars forming a constellation or asterism lie at the same distance from Earth, as though drawn on the ceiling in your classroom. In fact, the stars in the pattern vary greatly in their distances from Earth, with some being many times farther away than the others. They only appear to be twinkling from a flat surface because they are of similar brightness.

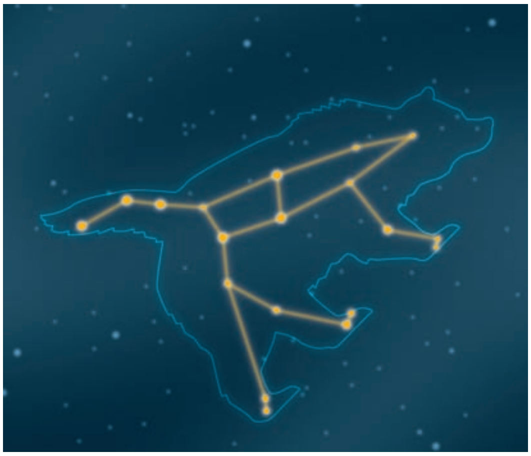


Figure 8.2 The constellation Ursa Major. To many cultures, this star pattern looked like a large bear.

Suggested Activity •
C12 Inquiry Activity on page 302

C11 *Quick Lab*

Reading Star Charts

Star charts are maps that show some or all of the 88 constellations and key stars that are visible from Earth.

Stargazers use star charts to orient themselves to the night sky, just like people use maps to find their way around new places on the ground. If someone told you about an interesting star cluster in the constellation of Aquarius, for example, knowing where to look on a star chart would allow you to see the star cluster too.

Purpose

To use a star chart to determine the location and appearance of well-known stars, constellations, and asterisms visible in the the northern hemisphere

Procedure

1. Working on your own, turn to the star chart in Skills Reference 12 or use the handout that your teacher gives you.

Questions

2. Looking at the star chart, answer the following questions.

(a) In which constellation is Polaris (the North Star) located?

(b) What planet is shown in the constellation Capricornus?

(c) Betelgeuse is a large star located in what constellation?

(d) What is the name of the constellation that has three bright stars in a row?

(e) What is the name of the star that seems to form the tail of the swan-shaped constellation known as Cygnus?

(f) Is the star Aldebaran located east or west of Betelgeuse?

(g) What is the name of the star cluster located midway between the constellations of Taurus and Perseus?

(h) What large star seems to form the right foot of the constellation commonly referred to as Orion the Hunter?

How a Star Is Born

Compared with the life span of humans, the life span of stars is extremely long. All stars form inside a collapsing nebula, a cloud of dust and gases. A nebula's collapse can be triggered by a disturbance such as the gravitational attraction of a nearby star or the shockwave from an exploding star.

Inside a collapsing nebula, the region with the greatest amount of matter will start to draw material towards it through gravity. This is where the star will form (Figure 8.4a). Material falling inward to the core has excess energy. This energy causes the central ball of material to begin to spin (Figure 8.4b). Extremely high pressures build up inside the ball, which in turn causes the tightly packed atoms to heat up. As the temperature climbs, the core begins to glow. This is a protostar (Figure 8.4c). A **protostar** is a star in its first stage of formation.

Eventually, the temperature of the spinning protostar rises to millions of degrees Celsius. This is hot enough for nuclear reactions to start. Over tens of thousands of years, the energy from the core gradually reaches the star's outside. When that occurs, the fully formed star "switches on" and begins to shine.

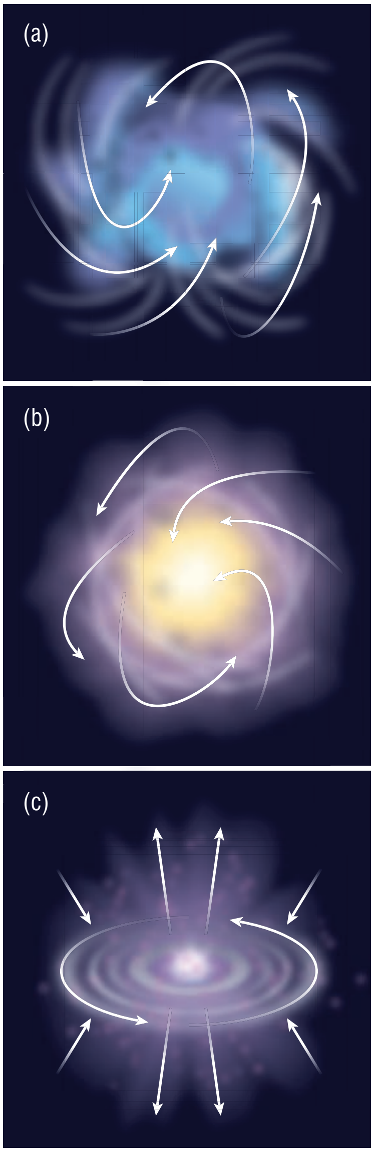


Figure 8.4 (a) As a region of a nebula collapses in on itself, gravity starts pulling dust and gas together into small masses. (b) As a mass grows, it begins a cycle of heating up, spinning, contracting (pulling inward), more heating, and so on. (c) The result of this process is a protostar.

The Life Cycle of Stars

A century ago, astronomers could tell that different kinds of stars existed. What they had not yet discovered was that stars have a predictable life cycle just like all living things do. It took the work of two researchers in the early 1900s to find the key to understanding star evolution.

Figure 8.3 Stars are "born" in nebulae, such as the Eagle Nebula shown here, with its aptly named star-forming "Pillars of Creation" region (inset).

Star Mass and Evolution

How a star evolves in its lifetime depends on the mass it had when it originally formed. Astronomers describe stars in three general mass categories: low, medium, and high. A low mass star, for example, advances through different phases than a high mass star does.

Low Mass Stars

Low mass stars use their nuclear fuel much more slowly than more massive stars do. Low mass stars burn so slowly that they can last for 100 billion years — more than eight times the current life span of the universe.

With less gravity and lower pressures than other stars, the nuclear reactions in the core of low mass stars happen at a relatively slow rate. The stars therefore exist a long time, shining weakly as small red stars called red dwarfs (Figure 8.5).

Like the light from a flashlight whose batteries are almost dead, the light of a red dwarf starts dim and gradually grows dimmer. As red dwarf stars run out of fuel, they collapse under their own gravity. This causes the star to reheat, but not enough that nuclear fusion can begin again. Most of the stars in the universe are red dwarfs.

Red dwarf stars eventually cool into smaller white dwarfs.

During Reading *Thinking Literacy*

Comparing Important Ideas

As you read about the evolution of stars, create a chart to compare the different types. Note the types of stars, their names, examples, and two important facts about each type. Which type of star has the longest life? Which type always comes to a violent end?

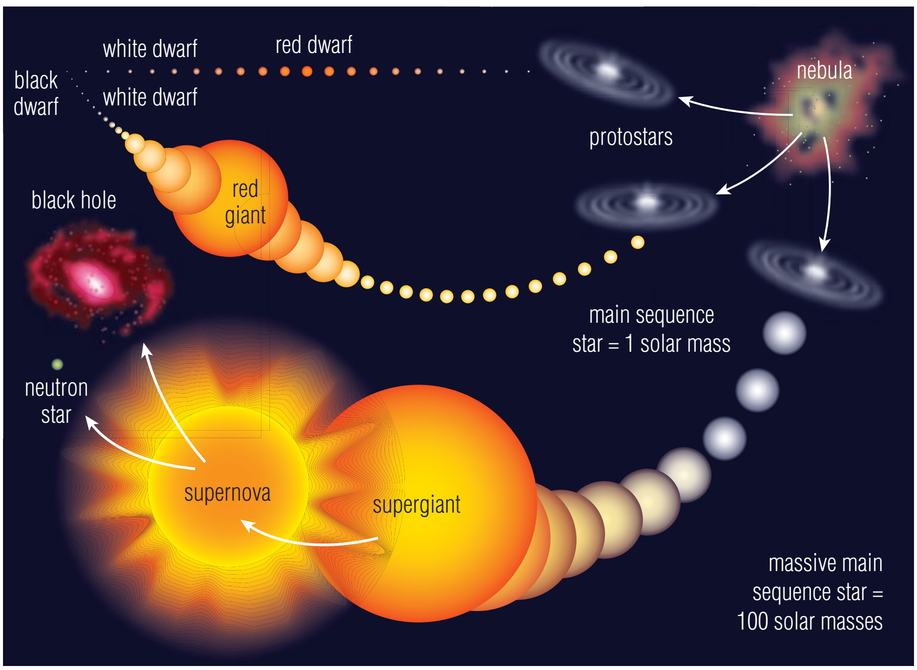


Figure 8.5 The three main life cycles of stars. What cycle a star goes through is determined by what mass the star first develops after its formation in a nebula.

Medium Mass Stars

Medium mass stars burn their fuel faster than low mass stars do, using their hydrogen up in about 10 billion years. The Sun is a medium mass dwarf star.

At the end of this long, stable period, the hydrogen fuel in a medium mass star begins to run out and the star slowly collapses under its own gravity. This process of collapsing raises the temperature and pressure again inside the star. This is enough to start the fusion of helium, which has been accumulating in the core. The star reignites. As the core heats up this time, the star expands rapidly into a red giant (Figure 8.5). Aldebaran, for example, is a red giant.

Eventually, even the helium fuel burns out and the star collapses again and slowly burns out.

High Mass Stars

High mass stars are those that are more than 10 times the mass of the Sun. In a high mass star, as gravity pulls matter into the centre of the star and squeezes the core, the nuclear reactions accelerate. As a result, a high mass star is hotter, brighter, and bluer than other stars (Figure 8.5).

Figure 8.6 Polaris, the North Star, is a supergiant. It is more massive than the Sun and 1000 times brighter. Unlike the Sun, however, Polaris is very unstable.

High mass stars always come to a violent end. After using up its hydrogen fuel, typically in less than about 7 billion years, such a star collapses just like a low or medium mass star does. The heating and compression cause helium to begin to fuse. During this process, tremendously high temperatures result, causing the star to expand into a supergiant. Examples of supergiants are Polaris (Figure 8.6) and Betelgeuse (Figure 8.7).

When the helium fuel runs out, the core again collapses into itself. The star continues to go through many cycles of collapse and expansion, as new elements, including iron, are formed in its core.

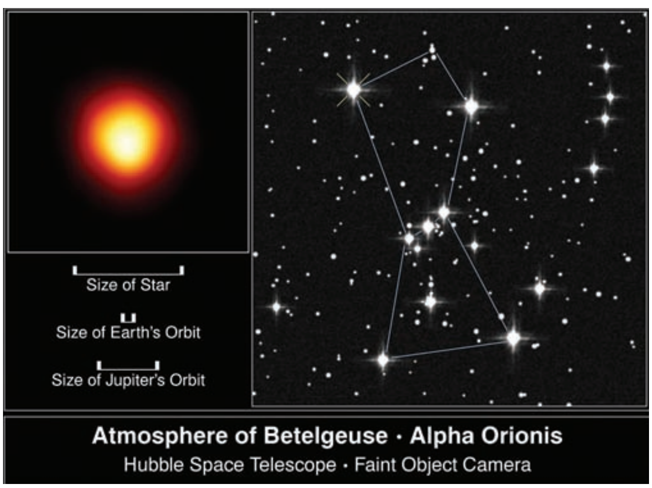


Figure 8.7 Betelgeuse is a red supergiant. It is so huge that if it were in the solar system where the Sun is, it would reach nearly all the way to Jupiter's orbit.

Supernovas: The Violent End of High Mass Stars

When iron fuses, it does not do so in a way that releases energy. If too much of the core of a high mass star is made up of iron, the star — which may have been shining continuously for more than 7 billion years — will "turn off" in minutes. With no fuel left to keep it producing heat energy, the star collapses one final time. So fast and intense is the collapse that the core of the star heats up to many hundreds of millions of degrees and explodes. As noted in section 7.1, an exploding star is called a supernova.

The explosion releases enough energy to cause the iron and other elements to fuse in various combinations (Figure 8.8). In this way, all the elements of the periodic table have been formed.

Figure 8.8 Are you wearing jewellery that contains silver or gold, or do you have a copper penny in your pocket? The atoms in all heavy elements were produced in a supernova.

The blast sends these heavy elements far out into space. Some of the debris and elements from the old star create new nebulae out of which new star-and-planet systems may begin to form.

The star's remaining core after a supernova explosion faces one of two outcomes, depending on the mass of the original star:

- *Neutron stars* — If the star was between 10 and 40 times the mass of the Sun, it will become a neutron star. A supernova explosion is directed not only outward, but also inward. This force causes the atoms in the star's core to compress and collapse. When an atom collapses, it forms neutrons, particles that are at the centre of most atoms already.

  When the star's core becomes little more than a ball of neutrons only about 15 km across, it is called a neutron star. Neutron stars are made of the densest material known (Figure 8.9).

- *Black holes* — If the star was more than 40 times the mass of the Sun, it will become a black hole. After exploding as a supernova, the star's core is under so much gravitational force that nothing can stop its collapse, not even the formation of neutrons. In this case, the effect of gravity is so great that space, time, light, and other matter all start to fall into a single point.

  As noted in section 7.1, black holes grow with the more mass they pull in.

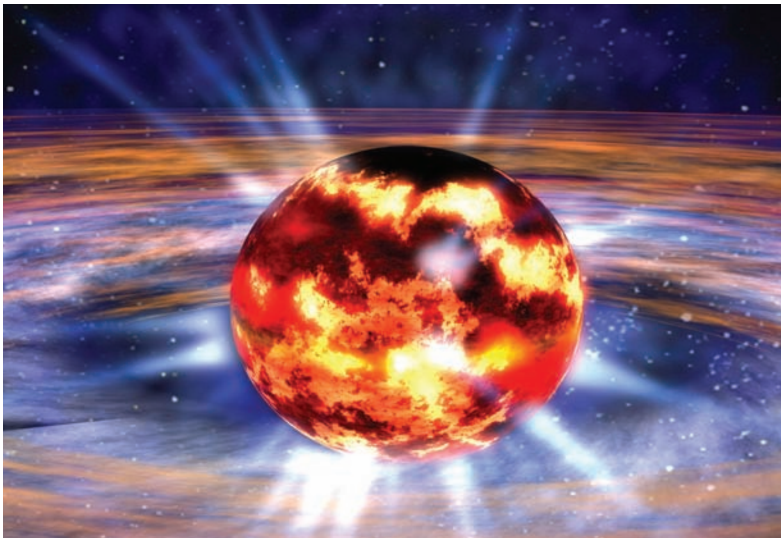


Figure 8.9 A neutron star. Imagine the dome at the Rogers Centre in Toronto being filled to the brim with steel and then that amount of steel being compressed to fit inside a 20-L fish tank. That is how dense the matter is in a typical neutron star.

The Hertzsprung-Russell Diagram

As the life cycle of stars shows, stars occur in many varieties. The differences between them include what colour they are, how bright (or luminous) they are, and even what their surface temperature is (Figure 8.10).

In 1919, two astronomers decided to sort and plot thousands of stars according to these three characteristics. Ejnar Hertzsprung and Henry Norris Russell wanted to find out whether any patterns might emerge that would tell us more about the nature of stars. The results of this survey and plotting work became one of the most important discoveries in astronomy in the 20th century.

Suggested Activity
C13 Design a Lab on page 303
C14 Quick Lab on page 304

The plotted data revealed for the first time that very clear relationships existed between star properties. Figure 8.11 shows a version of what is called the Hertzsprung-Russell diagram. In it, the stars are arranged as follows:

- by colour – Red stars are plotted on the right, and blue stars are plotted on the left. Other stars, such as the yellow Sun, are plotted in between.
- by luminosity – The brightest stars are plotted at the top, and the dimmest stars are plotted at the bottom. A star with a luminosity of 100 is 100 times brighter than the Sun.
- by surface temperature – The hottest stars are plotted on the left, and the coolest stars are plotted on the right.

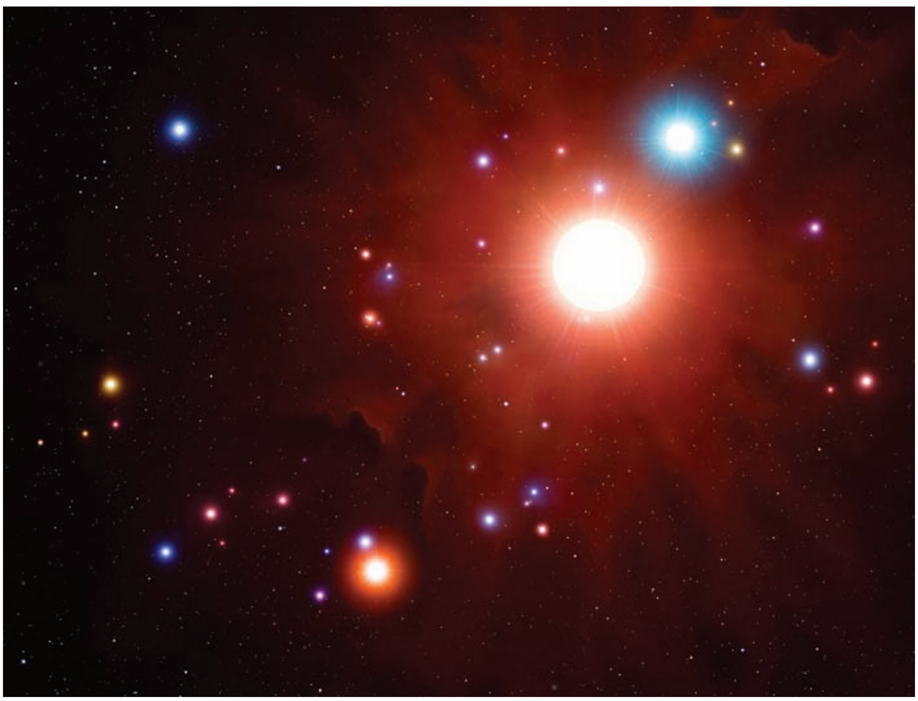


Figure 8.10 The stars shown in this binary system differ in colour, luminosity (brightness) and surface temperature.

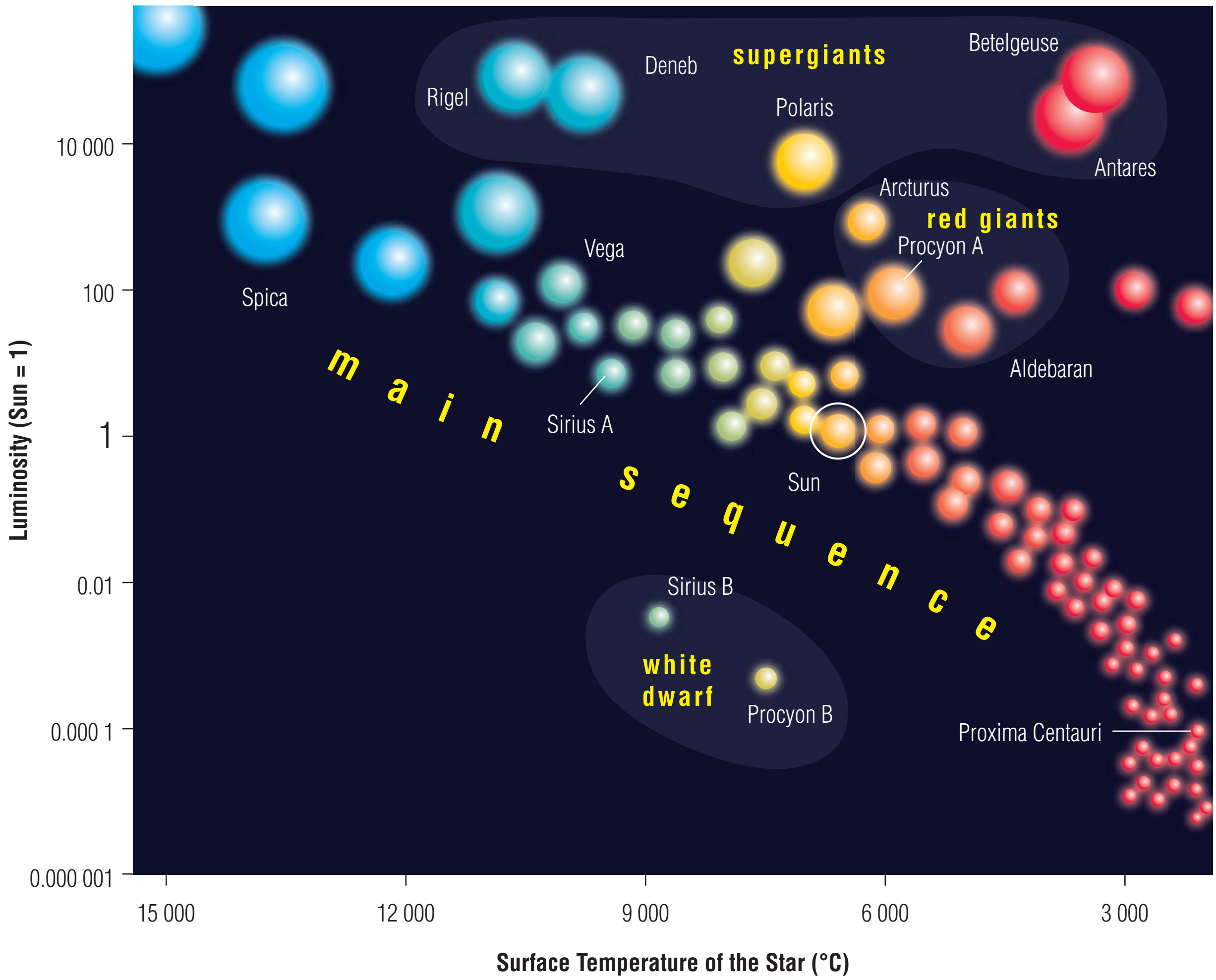


Figure 8.11 The Hertzsprung-Russell diagram represents the plots of thousands of stars based on colour, luminosity (brightness), and surface temperature.

The Hertzsprung-Russell diagram shows many patterns based on the three star properties noted above. For example, the star data forms a distinct band that stretches from the top left of the diagram to the bottom right. This is called the main sequence. The Sun is a main sequence star. These stars are thought to be in the stable main part of their life cycle. They have evolved to this stage since formation but will gradually either cool and die out or expand before exploding.

Groups of stars that do not appear along the main sequence are often near the end of their lives. At the bottom centre of the diagram are white dwarfs, such as the star Procyon B. They are white because they are hot, but dim because they are small. White dwarfs are cooling and will eventually become black. At the top right of the diagram are red giants such as Aldebaran and supergiants such as Betelgeuse and Antares. The outer layers of these stars are cool and appear red, but they are bright because they are so large. All of these giants will eventually explode.

Take It **Further**

Many different approaches have been taken to graphically displaying the data of the Hertzsprung-Russell diagram. Find at least three other versions to the one shown here and analyze how effective you think they are. Begin your research at ***ScienceSource***.

C12 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE

- Observing and recording observations
- Communicating ideas, procedures, and results in a variety of forms

Using a Star Chart

Your teacher will give you a simple star chart that can be used for early evening observations.

Question

How is it possible to locate the positions of stars in the night sky?

Materials & Equipment

- star chart
- flashlight with a red light (optional)

Procedure

1. While facing south, hold the chart over your head, with the chart facing you. Read the chart while looking up. Notice that east will be on your left and west will be on your right. This should match the labelling on the chart. A flashlight casting a red light will allow you to read your chart without having to let your eyes readjust to see the stars.

2. Locate the Big Dipper. Identify it first on your star chart. It is part of the constellation Ursa Major and has the shape shown below. Then, find the Big Dipper in the sky. You will see many more stars in the sky than appear on the chart, but the bright stars making up the Big Dipper should stand out.

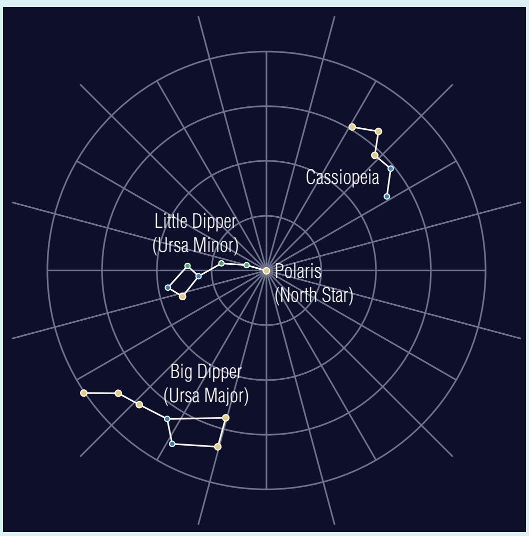


Figure 8.12 Three commonly observed constellations and Polaris

3. After you find the Big Dipper, locate the two stars that make up the outside of the ladle. These are know as the "pointer stars" because they point to Polaris, the North Star. Follow the pointer stars until you see a reasonably bright star. This is Polaris. It is always in this position in the sky no matter what the season or the time.

4. Follow along an arc until you reach a group of five stars that forms a big W. (Depending on the time of night and the season, this may look more like an M.) This is the constellation Cassiopeia.

5. Finally, go back to Polaris. It is part of the Little Dipper, forming the last star in the handle. The stars of the Little Dipper are not quite as bright as the stars of the Big Dipper, but they are still easily visible with the naked eye.

Analyzing and Interpreting

6. Describe how you used the Big Dipper to find Polaris, Cassiopeia, and the Little Dipper.

7. If you were unable to find any of these stars or groupings, explain what problems occurred that prevented you from locating them in the sky.

8. The star Sirius is brighter than Polaris. Would it make more sense to call Sirius the North Star, instead of Polaris? Explain your answer.

Skill Practice

9. Using your star chart, identify three other constellations in the northern sky.

Forming Conclusions

10. (a) If you were able to use the star chart effectively in this activity, write one guideline to add to the procedures that would help another student using a star chart for the first time.

    (b) If you were *not* able to use the star chart effectively, list one or more questions that you would need answered to help you find some or all of the identified objects.

C13 *Design a Lab*

Skills Reference 2

SKILLS YOU WILL USE

- Planning for safe practices in investigations
- Drawing conclusions

Star Light, How Bright?

Just as stars vary in mass, colour, and temperature, so they vary in brightness.

The brightness of stars viewed from Earth depends on both their actual brightness (luminosity) and their distance from Earth. If, for example, all stars had the same brightness, then we could assume that the ones that look dimmer to us from Earth are farther away than those that look brighter. In a similar way, identical flashlights held at different distances from us will appear to vary in brightness, too.

There are many aspects to the relationship between a light source's actual brightness and its distance from a viewer that can be explored. For example, is it necessary to double the distance of a light source from a viewer before the brightness of the light source is cut in half? In this activity, you will have an opportunity to investigate the brightness-distance relationship by using flashlights or LED penlights (but not laser sources of any kind) to assess changes in brightness related to distance.

Question

How does the distance of a light source from an observation point affect the apparent brightness of the light source?

CAUTION: Laser pointers of any kind, including LED laser pointers, are potentially damaging to the eyes and are not appropriate for this experiment.

Design and Conduct Your Investigation

1. Select a variety of light sources to use in your investigation. Possible light sources include non-laser light sources of different brightness such as penlight LEDs and flashlights with LED or incandescent bulbs.
2. Determine how you will safely measure light intensity from your various sources. For example: Will the light be projected onto a screen and the light intensity of the reflection observed, or will one partner shine light into another partner's eyes from different distances? How will the intensities of light be compared if they happen at different times or if different people make the observations? Can cameras be used? How will you make your measurements?
3. Design a procedure to carry out the investigation. Include in it a list of materials and equipment you will need. As well, design a data table to collect information on your brightness observations.
4. Ask your teacher to check the design of your procedure and data table.
5. Perform your investigation.
6. Prepare a formal lab report to document how you conducted the investigation. At the end of the report, summarize the results of your investigation in one or more paragraphs.
7. Consider how you could refine your investigation if you were to repeat it. Discuss your suggestions with your teacher.

Figure 8.13 Possible set-up for activity

C14 *Quick Lab*

Analyzing Stars by Their Spectral Patterns

Spectral patterns in stars are a little like star "fingerprints." By spreading a star's light into its spectral colours and "reading" the black spectral lines that appear, we can identify the individual chemical elements making up the star. Knowing what elements are in a particular star gives us information about how the star formed, whether it is likely to be surrounded by rocky planets like Earth, and how it will probably come to an end someday.

In this activity, you will analyze and compare spectral patterns to determine the chemical make-up of several stars.

Purpose

To identify the make-up of two mystery stars by analyzing their spectral patterns

Procedure

1. Looking at Figure 8.14, study the spectral patterns for the five elements shown.
2. Answer the questions below, recording your answers in your notebook.

Questions

3. Which three elements are visible iin mystery star A?
4. Which three elements are visible in mystery star B?
5. Which element listed in the spectral chart is not present in either mystery star?
6. Make a sketch of the spectrum that would be expected in a nebula that contains mainly hydrogen and lithium.

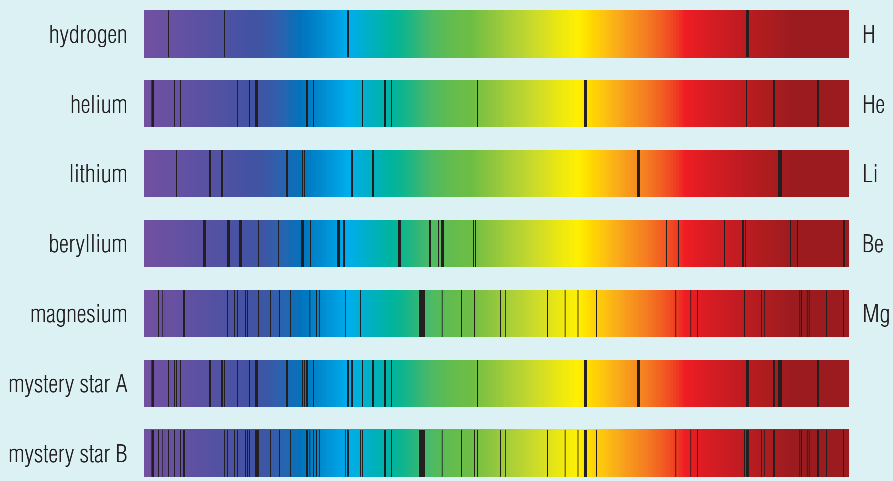


Figure 8.14 Spectral patterns for analysis

8.1 CHECK and REFLECT

Key Concept Review

1. (a) What is a constellation?
(b) How many official constellations are there?

2. What is a star called during its earliest stage of formation?

3. What process must occur inside a forming star before it can "switch on," creating its own light?

4. What main property of newly formed stars determines how the star will evolve?

5. Most stars in the universe are what type?

6. Name the three characteristics by which stars are plotted on the Hertzsprung-Russell diagram.

7. Explain the important concept about stars that was revealed by the Hertzsprung-Russell diagram.

8. Use the Hertzsprung-Russell diagram in Figure 8.11 on page 301 to answer the following questions.
(a) Which star's surface temperature is cooler, Antares or Vega?
(b) How many times more luminous is Polaris than Procyon A?
(c) The Sun is of too low a mass to explode in a supernova. As the Sun evolves and slowly dies out, on which part of the diagram would it be classified?

Connect Your Understanding

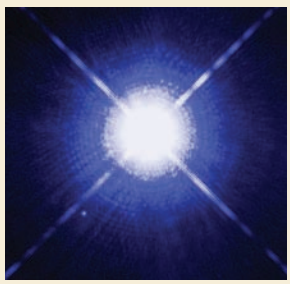
9. Describe how our view of constellations and asterisms in the sky and on star charts is misleading.

10. Using the Big Dipper as a point of reference, explain how you would help someone identify Polaris, the North Star, in the night sky.

11. Organize the following list in correct order of evolution.
(a) protostar
(b) nebula
(c) star
(d) red giant

12. Explain how the colour of a star is related to its:
(a) luminosity
(b) temperature

13. Sirius is orbited by a white dwarf known as Sirius B. In the image below, Sirius B is the tiny white dot to the lower left of Sirius. Sirius B has a mass slightly less than the Sun's mass. What inference can you make about the kind of star Sirius B will eventually become?



Question 13

Reflection

14. As you read in this section, newly formed stars evolve in one of three main ways. Think of a simple but creative method you could use to summarize and remember the stages in each of these life cycles.

For more questions, go to ***ScienceSource***.

8.2 The Solar System

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

- The solar system refers to the eight planets, their moons, and all the other celestial objects that orbit the Sun.
- The solar system formed from the leftover gas, dust, and other debris spinning around the newly formed star, our Sun.
- The Sun ejects a steady stream of charged particles called the solar wind. Earth's magnetic field deflects the wind, protecting life on the planet.
- The four rocky planets in the inner solar system are Mercury, Venus, Earth, and Mars. The four gaseous planets in the outer solar system are Jupiter, Saturn, Uranus, and Neptune.

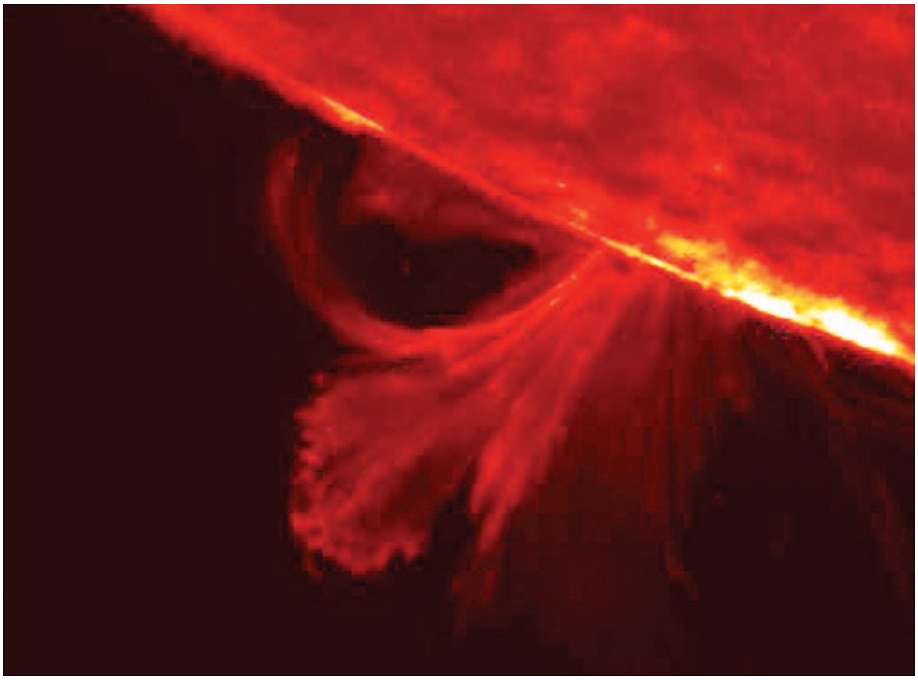


Figure 8.15 A solar flare erupting from the surface of the Sun

Our Solar Centre

The star at the heart of our solar system, the Sun, is the star we know better than any other in the universe. The Solar and Heliospheric Observatory (SOHO), a solar space telescope, has had a clear view of the Sun since 1995. The information it sends back to Earth, such as the image of the solar flare in Figure 8.15, shows us its fiery nature.

The Sun even experiences tornadoes. Tornadoes are powerful and destructive wind events that occur in many parts of North America, including southern Ontario. Recently, scientists have learned that tornadoes also occur on the Sun. A tornado on Earth is a vertical funnel of air that is a few hundred metres in diameter and rotates at speeds up to 500 km/h. A tornado on the Sun is much more extreme. A solar tornado is a tall funnel of twisting plasma.

The tornado shown in Figure 8.16 is more than 20 000 km in diameter, which would be large enough to contain Earth. It rotates at 500 000 km/h and has a temperature of several million degrees Celsius.

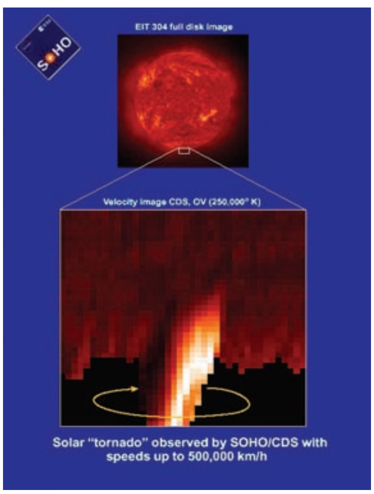


Figure 8.16 A solar tornado, with a temperature of several million degrees Celsius

While the Sun is a turbulent neighbour at times, Earth is the only planet in the solar system whose orbit is just the right distance away that a habitable environment for life is created.

DI Key Activity

C15 *Quick Lab*

Sizing Up the Solar System

Showing the distance between planets and the size of the planets on the same scale in one diagram in a textbook is impossible. If all the planets were sized large enough to be visible on the page, showing the distances to the same scale would make the diagram wider than your classroom.

Purpose

To explore the solar system by changing the scale of various objects inside and beyond it

Materials & Equipment

- 4 diagrams, each showing the following objects as a 5-cm disk: Earth, the Sun, the solar system, and the distance from the Sun to the next nearest star
- 1 diagram showing the Moon as a 1.5-cm disk
- grain of sugar
- metre stick or measuring tape

Procedure

1. Working in small groups, carry out each of the three tasks below. In each one, you are asked to predict the distance between two celestial objects at a particular scale. Use the hints provided, as well as what you may already know about the solar system. If necessary, make a "best guess."
2. At the end of each task, share your results with the class. Your teacher will then give out the correct answer so that you can carry out the next task with an understanding of the scales so far.
3. Task 1: Imagine shrinking Earth to be 5.0 cm in diameter. At this scale, the Moon is 1.5 cm in diameter and the Sun is 5 m (the length of a small truck). The distance from Earth to the Sun at this scale is 500 m (about five soccer fields long). Your task: Using this model scale, predict how far apart Earth and the Moon would be and then set them that distance apart.
4. Task 2: Imagine shrinking the solar system until the Sun is 5 cm in diameter. At this scale, Earth is the size of a grain of sugar. The Moon is a speck of dust about 5 mm from Earth. The farthest planet, Neptune, is about 200 m (about two soccer fields long) from the Sun. The next nearest star is 1500 km away. Your task: Using this model scale, predict how far apart the Sun and Earth would be and then set them that distance apart.
5. Task 3: Imagine shrinking the solar system again until Neptune's orbit around the Sun is 5 cm in diameter. At this scale, the Sun is smaller than the size of a "•" at the centre of the orbital disk and Earth lies about 1 mm from the Sun. Light from the Sun takes 8 min to reach Earth, 4 years to reach the next star, and 100 000 years to reach across the galaxy. Your tasks: Using this model scale, predict the following and then set the objects apart.
   (a) the distance between the solar system and the next nearest star
   (b) the size of the Milky Way galaxy

Questions

6. In this activity, you made a number of distance predictions based on different scales.
   (a) Which of your predictions were the most accurate?
   (b) Which of your predictions were the least accurate?
   (c) What can make predicting accurately a difficult thing to do?
7. The disk showing the solar system shows the eight planets roughly equally spaced in their distances from the Sun. In fact, the planets are not equally spaced. Suggest a reason why it was useful to show them spaced evenly.

During Reading | Thinking Literacy

All Ideas Are Not Equal

As you read, think about which information is most important to know and which is nice to know. In your notebook, draw a web showing the most important ideas in large circles and the "nice to know" ideas in smaller circles connected to the larger ones.

The Nature of the Sun

Our Sun is a good example of a typical star. Of medium size by star standards, it is composed mainly of hydrogen (73 percent by mass) and helium (25 percent by mass). The rest is made up of heavier elements including carbon, oxygen, and iron. It formed in the same way that all stars do, taking shape inside a nebula, the "stellar nurseries" of the universe. The Sun is believed to have first begun shining about 5 billion years ago and is expected to continue shining for about 5 billion years more before it runs out of fuel.

The Sun emits radiation of almost all forms found in the electromagnetic spectrum. The most obvious are visible light and ultraviolet (UV) radiation. Some forms of UV cause sunburn when a person's skin is exposed directly or indirectly to the Sun for too long.

Astronomers have estimated the Sun's mass by observing how fast the solar system's planets and other celestial objects orbit around it. Understanding how the Sun uses its hydrogen comes from discoveries made in the last century about atomic energy. The nuclear reactions taking place in the Sun are thought to be the same ones that occur in the most powerful kind of atomic weapon, the hydrogen bomb. In both cases, the reaction involves a small amount of hydrogen being converted into helium, which causes a rapid release of tremendous amounts of energy.

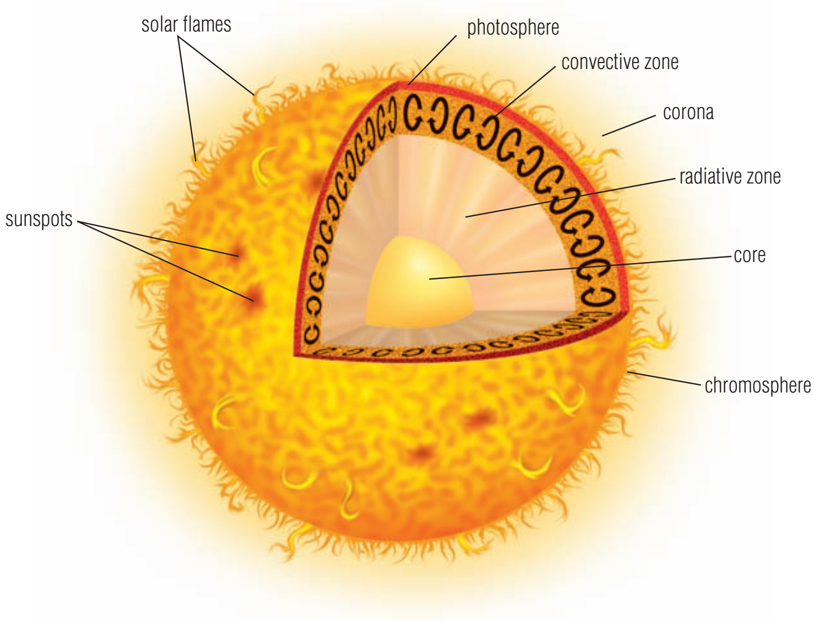


Figure 8.17 The layers and surface features of the Sun

The Sun's Layers

The Sun has six main layers, as shown in Figure 8.17.

Core

The inner part of the Sun is called its core. Here, pressures are high and temperatures are at least 15 million degrees Celcius. Nuclear fusion happens in the Sun's core. As discussed in chapter 7, nuclear fusion is a process in which light atoms fuse (meaning combine) and become heavier ones. During fusion, a small amount of matter is turned into a huge amount of pure energy.

Suggested Activity •
C16 Inquiry Activity on page 319

The fusion reaction creates helium, which concentrates in the Sun's core. The tremendous energy produced during fusion causes the surface of the Sun to swell outward, despite the tremendous pull from the Sun's gravity that causes the Sun's mass to collapse inward.

Radiative Zone and Convective Zone

Surrounding the core are two layers. The layer outside the core is called the radiative zone. The plasma is very dense here. Light and other forms of radiation are continuously absorbed and re-emitted in all directions. This layer extends three-quarters of the way up to the surface of the Sun. Light takes at least 100 000 years to pass up and through it. This means that the solar radiation we receive today was generated in nuclear reactions in the Sun's core more than 100 000 years ago.

The layer outside the radiative zone is the convective zone. In this region, huge bubbles of hot plasma ooze up toward the surface, carrying energy. Slightly cooler regions of plasma sink from higher levels in the zone to lower levels, where they warm up again. This constant circulation of plasma between hotter and cooler regions is called convection, which gives this layer its name.

Photosphere, Chromosphere, and Corona

The Sun does not have distinct edges between its layers, but the **photosphere** is usually considered to be the boundary between the inside and the outside of the Sun. This is the part of the Sun we see from Earth. It has the lowest temperature of all the layers, about 5500°C. The Sun's yellow colour originates in the photosphere.

Above the photosphere is a thin layer called the **chromosphere**. "Chromos" means coloured, and this layer has a red cast to it. Because the yellow photosphere is so bright, however, we can see the chromosphere only during a total solar eclipse (Figure 8.18) as discussed in section 8.3.

The **corona** is the outermost layer of the Sun and extends beyond the chromosphere for millions of kilometres. During a solar eclipse, when the corona is most clearly visible, astronomers are best able to make careful measurements of it.

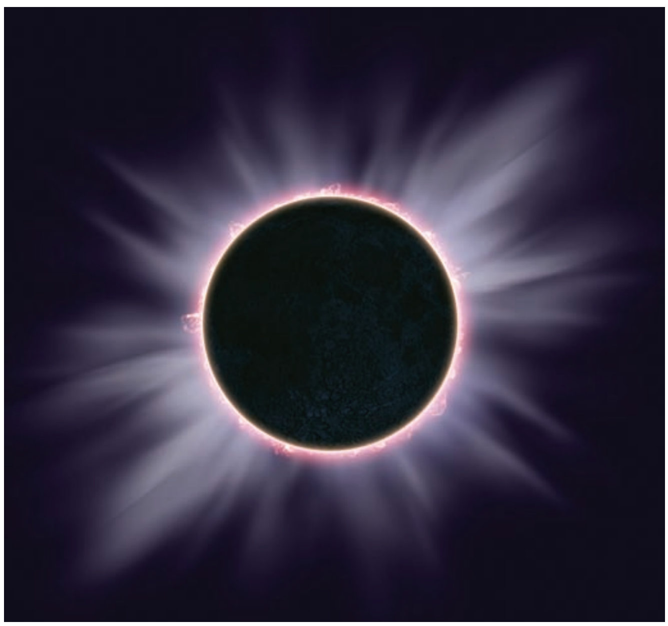


Figure 8.18 The Sun's thin red chromosphere. This zone has the same composition as the photosphere but is several thousand degrees Celsius hotter.

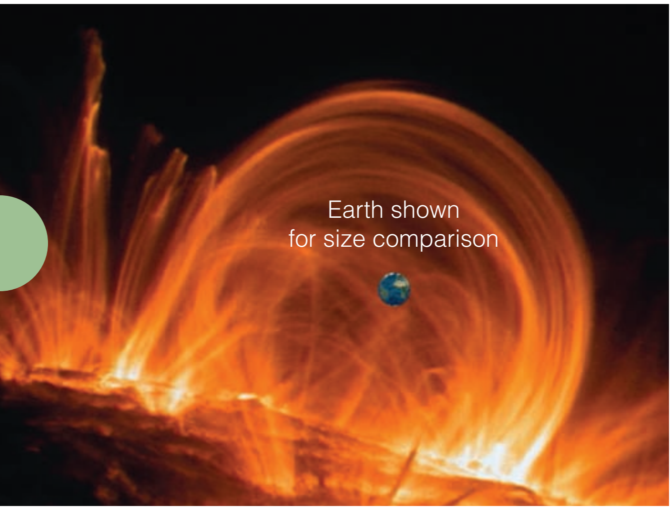


Figure 8.19 The magnetic field of the Sun is made visible by its effects on the plasma in the Sun's atmosphere. The field lines exit the Sun at one end of the arc and re-enter the Sun at the other.

Surface Features of the Sun

Both the Sun and Earth have magnetic fields. Earth's magnetic field produces the North and South Magnetic Poles. If you have ever used a hand-held compass, you have seen the magnetic field at work spinning the needle. The magnetic field is caused by spinning molten (meaning melted) metal deep in Earth's core.

The Sun also has a magnetic field, generated by movement of the plasma deep in the Sun's interior. The Sun's magnetic field extends far out into space where it is carried by the solar wind (as shown in Figure 8.22 on page 313). It is extremely powerful and can be seen in the way the Sun's plasma reacts (Figure 8.19).

The four main features on the surface of the sun are sunspots, prominences, flares, and coronal mass ejections.

Sunspots

A **sunspot** is a region on the Sun's surface that is cooler than the surrounding areas. Although still very bright, by contrast it looks darker than the surrounding areas (Figure 8.20). Sunspots indicate regions where the magnetic field is extremely strong, slowing down convection. This prevents the plasma from mixing, therefore allowing the region to cool from about 6000°C to 4000°C. Sunspots come and go. The number of them reaches a maximum every 11 years, increasing when the magnetic field strength of the Sun also reaches a maximum level.

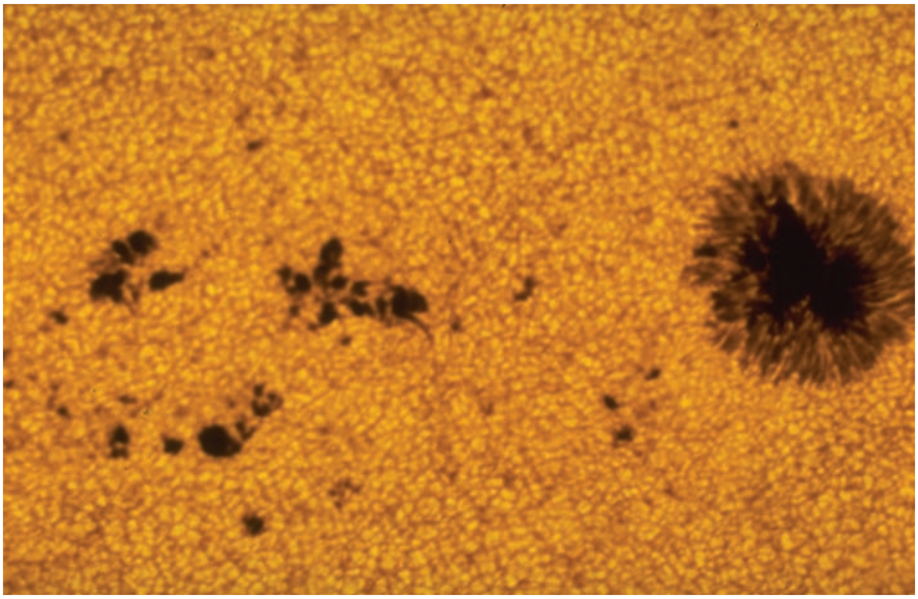


Figure 8.20 The dark zones surrounded by a lighter border are sunspots. Each is larger than Earth's diameter.

Prominences

A **prominence** is a large, often curved, bright stream of particles extending outward from the photosphere into the corona. Frequently the curved shape forms a complete loop (Figure 8.21). The electrically charged plasma in the prominence allows the prominence to be shaped by the magnetic field. This makes part of the magnetic field visible. A prominence may last for many hours.

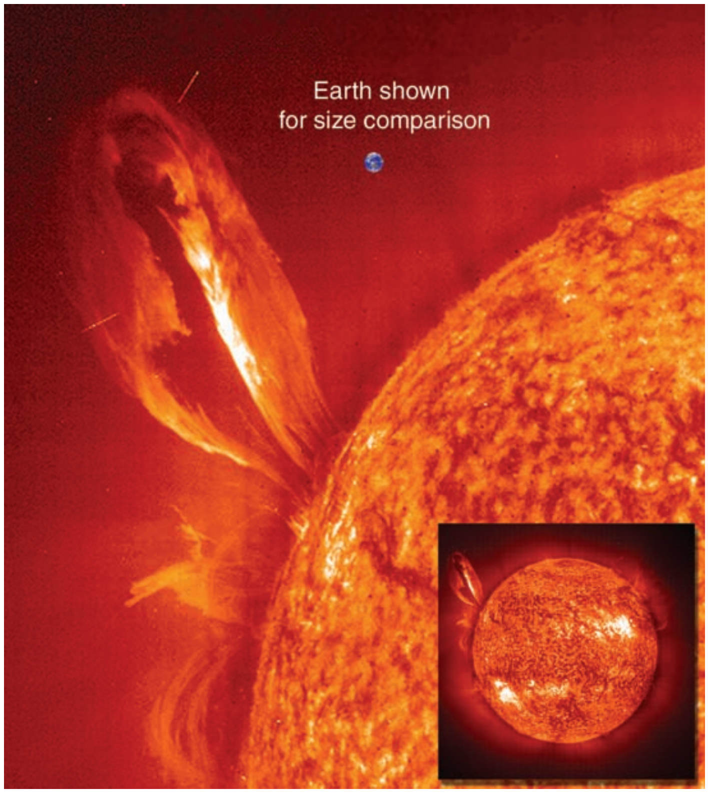


Figure 8.21 A large prominence with Earth shown for size comparison

Solar Flares

A **solar flare** is a massive explosion at the surface of the Sun. It usually originates where the magnetic field breaks out of the Sun's surface and interacts with the chromosphere and corona. This sudden release of magnetic energy flings hot plasma out into space, which we see as a long bright filament extending out from the Sun. Figure 8.15 at the start of this section shows a solar flare.

An extremely powerful kind of flare is called a **coronal mass ejection**. When this occurs, a large amount of plasma is thrown out through the corona and into space at a speed of more than 1000 km/s. Sometimes, a coronal mass ejection may be pointed directly at Earth. When this plasma stream reaches Earth about three days later, it meets Earth's magnetic field. Our magnetic field protects Earth by diverting much of the plasma away from the planet's surface. This causes particularly vivid and active auroras, as described on the next page. It can also damage orbiting satellites and electrical transmission lines on the ground.

Learning Checkpoint

1. Which two elements make up more than 99 percent of the Sun?
2. Where in the Sun does nuclear fusion occur?
3. What is the difference between the radiative zone and the convection zone in terms of how energy is transferred up toward the outside of the Sun?
4. Name four types of surface features on the Sun.
5. How can a coronal mass ejection on the Sun cause damage on Earth?

The Sun's Effects on Earth

As you have read, the Sun warms Earth and supports every form of life on the planet. In addition to these significant influences, there are many other ways the Sun affects our planet. The solar wind and aurora borealis are two of these ways.

The Solar Wind

The tremendous amount of heat at the surface of the Sun produces a thin but steady stream of subatomic particles. This constant flow of particles, streaming out of the Sun's surface in all directions, is called the **solar wind** (Figure 8.22).

Early in the solar system's history, the solar wind blew against the nebula from which it formed. This pushed the gas and dust away from the Sun. The material that was not blown away continued to swirl around the Sun. The swirling motion caused the dust, rocks, and gas that had not fallen into the protostar to form into a thin disk. It is from within this disk that all the other bodies in the solar system took shape.

During turbulent solar times, electronic equipment and devices on Earth may be damaged by higher-than-normal blasts of charged particles from the Sun.

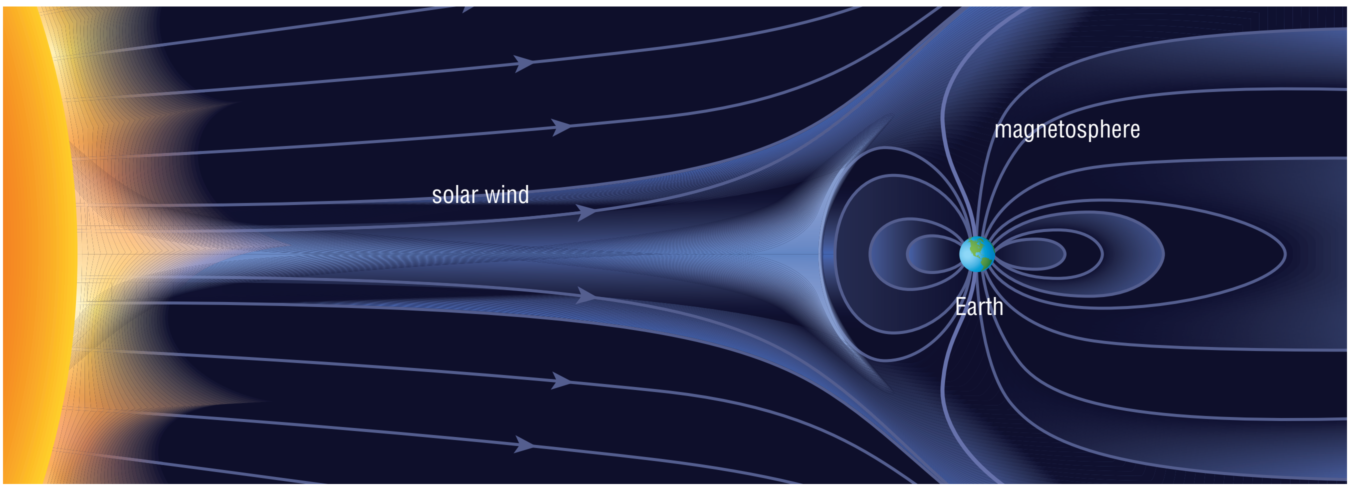


Figure 8.22 The solar wind crosses space and strikes Earth. Earth's protective magnetic field, the magnetosphere, deflects most of this solar wind.

The Aurora Borealis

The solar wind is responsible for creating the breathtaking displays of green, yellow, and red light in the skies near Earth's northern and southern regions. In the northern hemisphere, these light displays are called the **aurora borealis** (the Northern Lights). In the southern hemisphere, they are called the aurora australis (the Southern Lights).

The aurora borealis is produced when the charged particles of the solar wind collide with the atoms and molecules in Earth's atmosphere. An aurora (meaning a glow) forms as particles from the solar wind are trapped by Earth's magnetic field and are swept toward the North and South Poles (Figure 8.23).

Figure 8.23 The aurora borealis

How the Solar System Formed

After the Sun formed, the leftover dust, gases, and other debris in the nebula continued to spin, creating a disk around the new star. Small bodies began to form, growing into the planets, moons, asteroids, and comets that make up the solar system (Figure 8.24). This process, astronomers believe, is how other star-and-planet systems in the universe have formed as well.

After the Sun, the next largest bodies in the solar system are the eight planets. A **planet** is a celestial object that orbits one or more stars and is capable of forming into a spherical shape as it melds under the weight of its own gravity. A planet does not create and radiate its own light like a star does. It only reflects the light of the star or stars that it orbits.

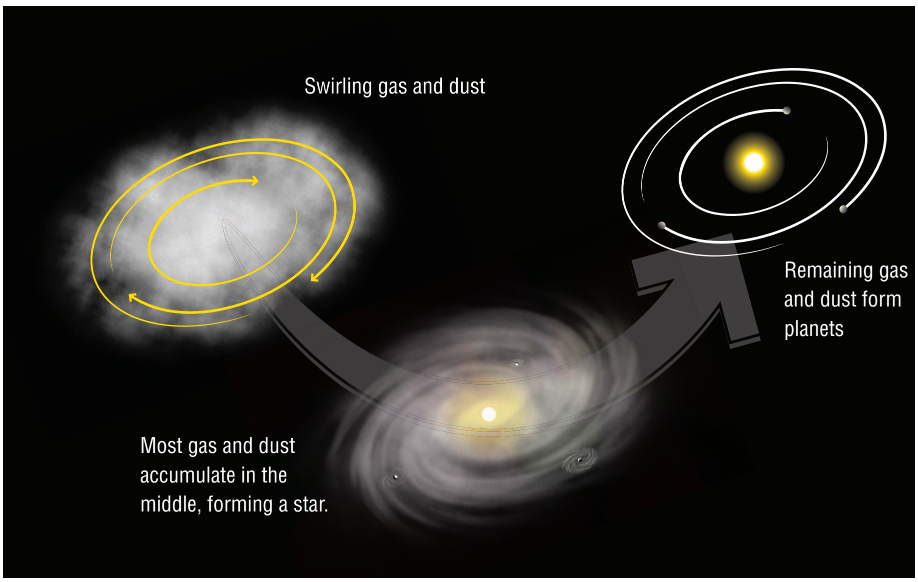


Figure 8.24 The solar system formed when the gas and dust left over from the formation of the Sun continued to spin around the star. Gravity caused the material to clump together and contract, creating a range of celestial objects, from planets and moons to asteroids and comets.

The Rocky Inner Planets

As the spinning particles of dust and gas slammed into each other during the early stages of the solar system's formation, some of the particles began sticking together. Larger particles tended to grow faster than smaller ones because they were involved in more collisions. This is similar to a large snowball growing faster when you roll it in sticky snow than a small snowball does.

As these objects got bigger in mass, gravity caused them to contract and bind together even more strongly. Objects orbiting too close to the Sun gradually fell into it, drawn by its gravitational force. They burned up. However, four large objects lasted and eventually formed into the four rocky planets, Mercury, Venus, Earth, and Mars (Figure 8.25; see the planet summaries on page 316).

Earth's Moon

Within a few hundred million years after forming, the young Earth may have been struck by an object nearly the size of the planet Mars. In this enormous collision, both of the objects re-melted and mixed. The metal core at the centre of the Mars-sized object shot through its melted crust and plunged deep into Earth where it merged with Earth's metallic core. The rocky crusts of Earth and the Mars-sized object mixed, but the momentum of the collision destroyed much of the rest of the material. The larger object cooled down to become Earth as we know it today. The smaller object, likely formed from material torn from Earth after this collision, became trapped by Earth's gravity. It existed first as debris and rubble, but eventually it compacted into a new object, the Moon.

Mars is the only other of the rocky planets with a moon, and it has two, Phobos and Deimos.

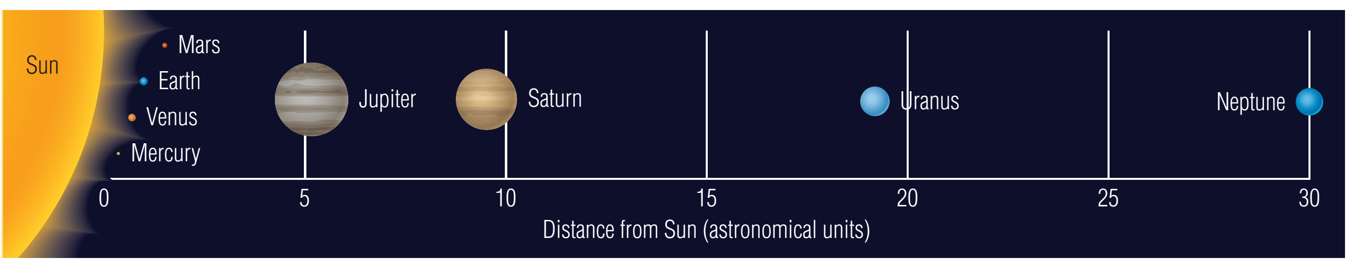


Figure 8.25 The solar system. The four rocky planets closest to the Sun were the first to form. The four gaseous planets in the outer solar system took shape later.

The Asteroid Belt

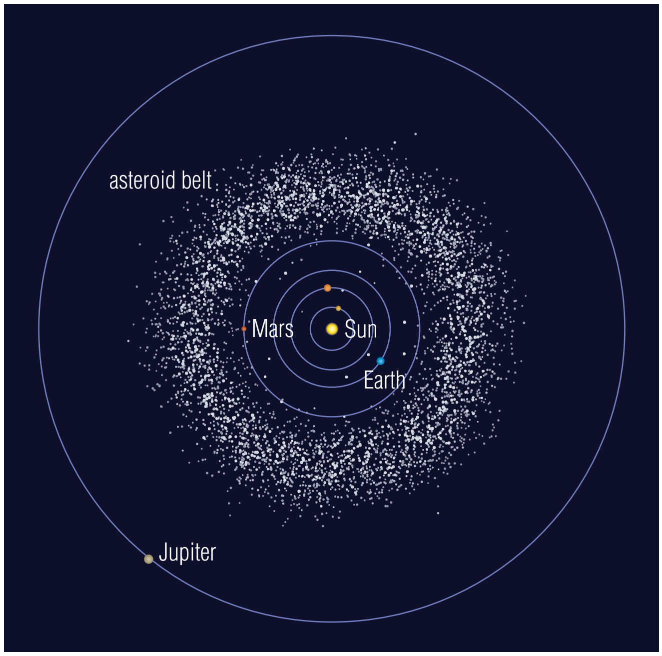


Figure 8.26 The asteroid belt lies between the orbits of Mars and Jupiter.

Past the orbit of Mars lies a huge band of rocks that is spread out in a vast ring circling the Sun (Figure 8.26). Some of the rocks are as large as 1000 km across, about the distance between Ottawa and Thunder Bay. Others are as small as grains of sand. This is the asteroid belt.

Some scientists looking for Earth-like planets in other star systems are doing so by looking for the presence of an asteroid belt around the star. If there is such a band, this might indicate that rocky planets are orbiting the star as well.

It is the analysis of asteroids that has given us the estimated age of the solar system. Occasionally, asteroids fall from their orbit and crash to Earth. By the 1950s, scientists had found a way to determine the age of many asteroid specimens. The oldest ones were dated at 4.56 billion years old. Because Earth would have formed at the same time as the asteroids did, researchers have used this asteroid-dating technique to date Earth. As it took time for the asteroids to form, the Sun and solar system are currently estimated to be about 5 billion years old.

The Four Gaseous Outer Planets

The solar wind blows gases away from the Sun, but this does not mean that all the gases escape the solar system completely. Just beyond the asteroid belt is the "snow line." On the Sun side of this line, the Sun's radiation keeps water in its gaseous phase. However, out past the snow line, water can cool to form droplets and then freeze.

Astronomers believe that the four largest planets in the solar system may have grown as they did because ice acted as a kind of glue to cause gas and dust particles in the outer regions of the solar system to stick together. In fact, these planets grew much faster even than the rocky ones did. The result was the four gas giants: Jupiter, Saturn, Uranus, and Neptune (see the planet summaries on page 317).

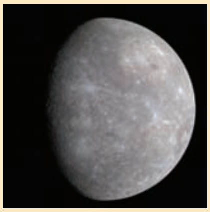
All of the gas giants are orbited by numerous moons. Jupiter and Saturn each have more than 60 moons (Figure 8.27).

Figure 8.27 Io, a moon of Jupiter, is shown here orbiting the large planet.

The Rocky Planets

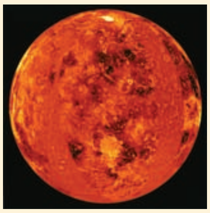
Planet	Average Distance from Sun (AU)	Radius (km)	Mass (Earth mass)	Average Surface Temperature (°C)	Period of Rotation (Earth day)	Period of Revolution (Earth year)
Mercury	0.4	2400	0.1	180	60.00	0.2
Venus	0.7	6100	0.8	470	240.00	0.6
Earth	1.0	6400	1.0	17	1.00	1.0
Mars	1.5	3400	0.1	–60	1.03	1.7

Mercury



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

Venus

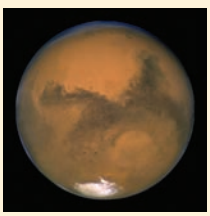


Venus is similar to Earth in diameter, mass, and gravity, and is often called Earth's twin. However, Venus would be unfit for humans to visit. Surface temperatures are kept hot by a greenhouse effect caused by thick clouds. Temperatures can be over 450°C, hot enough to melt lead. The atmospheric pressure is about 90 times that on Earth. Venus's surface cannot be seen by telescope because of its thick cloud cover. The permanent clouds, made of carbon dioxide, often rain sulphuric acid (the same acid found in a car battery). Russia landed a probe on Venus in 1982, but it stayed operational for only 57 min. In 1991, the spacecraft *Magellan* mapped Venus using radio waves (radar). The *Venus Express* orbiter arrived in 2006 and continues to make atmospheric studies. It has found huge canyons, extinct volcanoes, and ancient lava flows. Venus is one of only two planets in the solar system to rotate from east to west, the opposite direction to the other six.

Earth

Earth is unique in the solar system for several reasons. It is the only planet where water exists in all three states: solid, liquid, and gas. It is also the only planet that is at the appropriate distance from the Sun to support life as we know it. Earth is protected from solar and cosmic radiation by its atmosphere and its magnetic field. The ozone in the atmosphere screens life on Earth from ultraviolet (UV) radiation. The magnetic field makes most of the charged particles from the solar wind and cosmic rays stream around the planet, far outside the atmosphere. Water covers 70 percent of the planet's surface. Earth is one of the few planets in the solar system that has active volcanism.

Mars



Mars has been studied by telescope for centuries. It is often referred to as the "red planet," though it is actually more orange in colour. This appearance is caused by the iron oxides on the planet's surface. Mars has two polar ice caps: one is made up of frozen carbon dioxide and water, and the other is made up of carbon dioxide only. The atmosphere is very thin and composed mainly of carbon dioxide. Although the average surface temperature is extremely cold, temperatures at Mars's equator can reach 16°C in the summer. Like Venus and Earth, Mars has canyons, valleys, and extinct volcanoes. Mars has two small moons.

The Gaseous Planets

Planet	Average Distance from Sun (AU)	Radius (km)	Mass (Earth mass)	Average Surface Temperature (°C)	Period of Rotation (Earth day)	Period of Revolution (Earth year)
Jupiter	5.3	71 000	320	–150	0.41	12
Saturn	9.5	60 000	95	–170	0.45	30
Uranus	19.0	26 000	15	–215	0.72	84
Neptune	30.0	25 000	17	–215	0.67	165

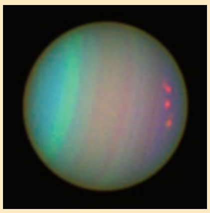
Jupiter

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

Saturn

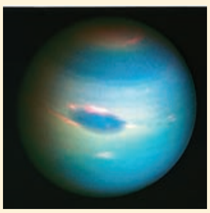
Saturn is the second-largest planet in our solar system and has the most distinctive ring system of all the eight planets. Over a thousand rings exist, composed of pieces of ice and dust that range in size from grains of sand to house-sized blocks. The Italian astronomer Galileo saw Saturn's rings with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

Uranus



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

Neptune



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

Suggested Activity •
C17 Problem-Solving Activity on page 320

The Minor Planets

Beyond the gas giant planets, a number of very large balls of ice formed. These have come to be called minor, or dwarf, planets, the most famous of which is Pluto. Pluto is large enough to hold three icy moons. Nix and Hydra are tiny. Charon is about half the size of Pluto.

There are millions of small objects besides Pluto and Charon orbiting the Sun. Some are larger than Pluto, but most are smaller. Together, they create a thin disk that, like the asteroid belt, forms a ring around the entire solar system. About 25 of these are large enough, however, to be considered minor planets.

Take It Further

In 2000, the first space probe ever to orbit an asteroid reached Eros in the asteroid belt. Eros measures 33 km by 13 km. Find out the purpose of the mission to Eros and whether it succeeded in its task. Begin your research at ***ScienceSource***.

Comets and Meteors

The most distant region of the solar system is the Oort Cloud. It consists of billions of fragments of ice and dust, and is thus a major source of comets. A **comet** is a celestial object made of ice and dust. When a gravitational disturbance causes one to change its orbit and fall nearer the Sun, the Sun heats the comet, causing some of its ice particles to break away. Carried away from the Sun by the solar wind, these icy particles spread out into a tail millions of kilometres long, lit up by the Sun (Figure 8.28). Comets can sometimes be seen from Earth, passing slowly across the sky over several days.

Also visible from Earth are meteors, which streak brightly through the sky in seconds. You may have heard these referred to by the colourful but incorrect nickname of "shooting star." Meteoroids are small pieces of rock or metal that travel throughout the solar system with no fixed path. They are thought to be similar in origin to asteroids and comets. A **meteor** is a meteoroid that, upon entering Earth's atmosphere, begins to burn up as a result of friction. If a meteor does not burn up completely and strikes Earth's surface, it is called a meteorite.

Figure 8.28 Most comets have been orbiting the Sun in the Oort Cloud for billions of years. Because of their composition, they are often referred to as "dirty snowballs."

SKILLS YOU WILL USE
- Conducting inquiries safely
- Identifying sources of error

Measuring the Sun's Diameter

The distance from Earth to the Sun has been measured to be about 150 million km. With this information, we can make a measurement of the Sun's diameter without looking directly at the Sun. How we do this is by using an apparatus that takes advantage of the property of similar triangles. If each of the three angles in triangle A is the same as the corresponding angle in triangle B, then we know that the size of triangle A will be exactly proportional to the size of triangle B. For example, if you know the length of the sides of triangle A, even if it is only in centimetres, you can calculate the length of the sides of triangle B, even if it is many times larger than A.

Question

How can the diameter of the Sun be measured safely and accurately?

Materials & Equipment

- Imaging apparatus (see Figure 8.29)
- metre stick
- calculator

CAUTION: Never look directly at the Sun.

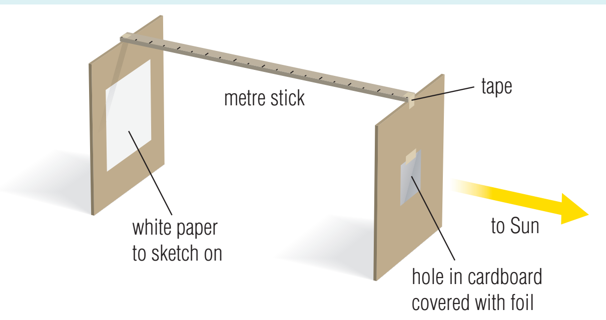


Figure 8.29 Assembly of apparatus

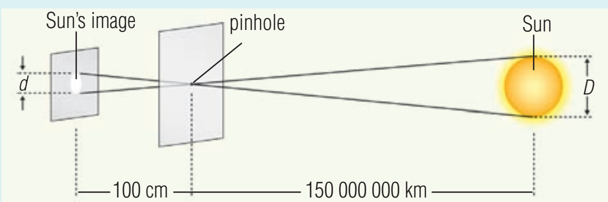


Figure 8.30 Capturing the Sun's image

Procedure

1. Move outside. Hold the apparatus with the screen against your stomach to keep it steady. Move the metre stick until the image of the Sun's disk appears on the white paper.
2. Mark the diameter of the Sun's image on the paper. Repeat several times and average the result.
3. Calculate the Sun's diameter in kilometres, using the average image diameter in centimetres (see Figure 8.30). Because the Sun's diameter and Sun's distance from the pinhole create a similar triangle to the triangle created by the Sun's image and the image's distance to the pinhole, the following formula can be used to calculate the diameter:

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

where d = diameter (cm) and
D = Sun's diameter (km)

Analyzing and Interpreting

4. Your teacher will give you the accepted value. Compare yours with it. How did you do?
5. Suggest two ways to improve making the measurement.

Skill Practice

6. A student makes a measurement using an imaging apparatus that is 50 cm long. The image diameter is measured to be 1 cm. What value would be calculated for the diameter of the Sun?

Forming Conclusions

7. Compare your results with those of other members of the class to ensure that you have done the calculation properly.
8. State your results for the diameter of the Sun.
9. At the end of your work, return the apparatus to your teacher.

C17 *Problem-Solving Activity* Skills References 3, 6

SKILLS YOU WILL USE
- Defining and clarifying the inquiry problem
- Thinking critically and logically

A Model of the Solar System

Recognize a Need

You have been asked to generate a graphic representing the solar system with correct scales for planet diameters and distance of planets from the Sun. The graphic should be meaningful to younger students interested in astronomy.

Problem

How can the scales for planet diameter and distance from the Sun be displayed on the same graphic?

Materials & Equipment

- ruler
- geometry compass
- scissors
- coloured markers
- note paper
- 1 piece of flipchart paper
- glue or tape

Criteria for Success

- The planets are drawn to a correct scale by diameter and are labelled and coloured appropriately.
- The planets are positioned to a correct scale to represent their distance from the Sun.

Brainstorm Ideas

1. Working with a partner, use the data from the planetary charts on pages 316–317 to determine what scale would give your solar system graphic the best and most accurate fit on a piece of flipchart paper.
2. The Sun will be too large to fit on your graphic. Just show a curved edge of the Sun on one side of the paper, or think of some other way to represent the Sun.
3. It will not be possible to use the same scale to represent the planet diameter and the planet distance from the Sun. Therefore, determine a different scale to show your solar system distances.
4. Make a table showing each planet's real diameter (km) and distance from the Sun (AU). Then, add two columns to the table and write in the model diameter (cm) and distance from the Sun (cm) that you will use in your solar system graphic.

Make a Drawing

5. Draw each planet separately on a piece of paper according to your scale (in cm). Cut the sphere out. (Depending on your scale, your cut-out may have to be larger than the actual planet drawing.) Colour each planet based on information you read in section 8.2.
6. On the flipchart paper, draw the curve of the Sun as recommended in step 2. Then, measure the distance from the Sun each planet should be positioned in your model. Glue or tape each planet in place, ensuring it is labelled.

Test and Evaluate

7. Check that none of the planets overlap each other. If any do, you will need to modify your design so that they do not overlap. You may need to change the scales, but the relative distances from the Sun or diameter must still be correct.

Skill Practice

8. Explain how you converted the diameter or distance of the planet from the Sun in km or AU into units of cm.

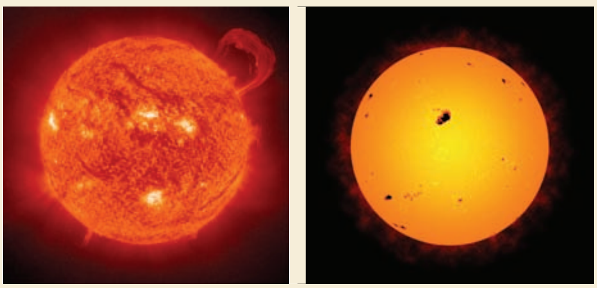
Communicate

9. Check with your teacher about placing your graphic on the classroom wall.

8.2 CHECK and REFLECT

Key Concept Review

1. The Sun is composed almost entirely of what element?
2. (a) How long has the Sun existed?
   (b) How much longer is it expected to shine?
3. List the six layers of the Sun from the core out.
4. How many years ago was the radiation you see and feel from the Sun today produced by nuclear reactions inside the Sun?
5. Name the surface feature of the Sun shown in each image (a) and (b) below.



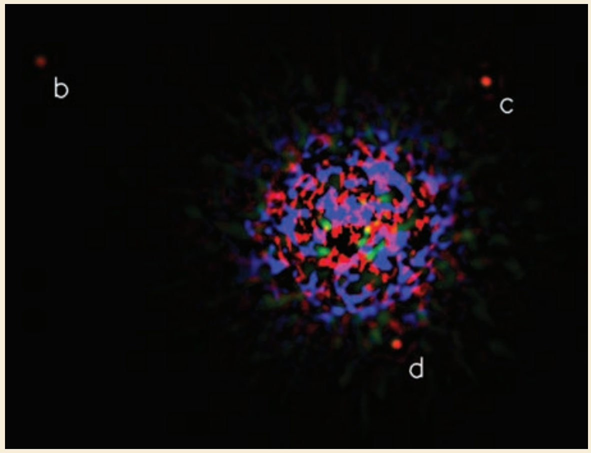
(a) (b)

Question 5

6. Explain what causes the astronomical phenomenon known as the aurora borealis.

Connect Your Understanding

7. Compare and contrast the four inner planets with the four outer planets in terms of composition, size, shape, and position in the solar system.
8. The Moon does not have a dense metallic core as Earth does and instead appears to be composed only of the same materials as are found in Earth's outer layers. Based on this information, what conclusion can be drawn about the formation of the Moon?
9. In 2008, Canadian astronomers were the first to capture an image of three planets orbiting a star far from the solar system (see below). Make a sketch to illustrate the accepted theory of how a star-and-planet system such as this formed.



Question 9 The star around which these three planets have been discovered in orbit lies 160 ly from Earth.

10. Explain why the presence of an asteroid belt around other stars besides the Sun might be evidence that Earth-like planets might exist.
11. What is the relationship between the position of the "snow line" in the solar system and the size of the planets on either side of it?
12. Why would it be unreasonable to expect Saturn-like rings around any of the inner planets in the solar system?

Reflection

13. In reading about the scale of the solar system and working through the related activities in this section, what did you learn that impressed you most about the relative size of the solar system objects and the distances between them?

For more questions, go to ***ScienceSource***.

8.3 Earth, the Sun, and the Moon

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

- Earth rotating on its axis produces day and night. Earth revolving around the Sun once a year produces the seasons.
- As the Moon revolves around Earth, the amount of the Sun's light the Moon reflects back to Earth changes. These changes create the phases of the Moon.
- In a solar eclipse, the Moon moves between Earth and the Sun, casting a shadow on part of Earth. In a lunar eclipse, Earth moves between the Moon and the Sun, casting a shadow on the Moon.
- Tides result from the gravitational effects of the Moon and the Sun on Earth and its oceans.

Figure 8.31 Midnight in the Arctic during the peak of summer

Earth in Motion

If you lived in a region near Earth's equator, you would notice little change from day to day throughout the year in the hours of daylight relative to the hours of darkness. Every day all year long, about 12 h of daytime would be followed by about 12 h of night. The farther north or south of the equator a person lives, however, the bigger the range he or she sees in daily hours of light over a year.

In the northern hemisphere, we experience the hours of daylight changing in a non-stop cycle, lengthening as we move into summer and shortening as we move into winter. No matter where you live in Ontario, think how different it is at 5 p.m. on a December afternoon compared with 5 p.m. on a July afternoon. The greatest daylight extreme is in Arctic regions, where the Sun does not set some days at the peak of summer and does not rise some days at the peak of winter (Figure 8.31).

The reason for this tremendous variation is that Earth spins like a top around a tilted axis, the imaginary line running through the planet. As it spins, Earth also revolves around the Sun. These two motions cause day and night, season changes, and what looks from Earth to be movement of the Sun and the stars across the sky.

C18 Quick Lab

The Effects of Earth's Motion on Our View of the Sky

Early people were well aware that when they observed the position of the Sun and constellations shifting in the sky, a seasonal change was coming.

Purpose

To simulate the relationship between Earth's motion, the position of celestial objects as viewed from Earth, and the changing seasons

Materials & Equipment

- diagrams of Polaris (the North Star), Cassiopeia, Little Dipper, Big Dipper, Orion, Leo, Scorpius, and Pegasus
- masking tape or thumb tacks

Procedure

1. Your teacher will tape the diagram of Polaris on the ceiling in the centre of the room and tape the diagrams of Cassiopeia, Little Dipper, and Big Dipper around Polaris in their correct orientation.
2. On each of the four walls in the room, tape the following diagrams: Orion (winter) on the west wall, Leo (spring) on the south wall, Scorpius (summer) on the east wall, and Pegasus (autumn) on the north wall.
3. Have one student be the Sun, standing in the middle of the room.
4. Have another student be Earth. Earth stands to the west of the Sun and facing the Sun. In this position, Earth's northern hemisphere is in winter and the time of day on Earth's front is noon. Earth cannot see any stars because the Sun's light is outshining them.
5. Earth slowly turns in a counter-clockwise direction until Earth's front experiences midnight. Note which star pattern on the wall Earth can now see and how the Big Dipper is oriented.
6. Repeat steps 4 and 5 for the other seasons by having Earth stand south, east, and north of the Sun.

Questions

7. What motion of the person playing Earth
   (a) represents the passing of 1 day on Earth?
   (b) represents the passing of 1 year on Earth?
8. With the person representing Earth rotating counter-clockwise, does the Sun rise on the left side or the right side of Earth's face?
9. Explain why different constellations are visible in the evening in different seasons.
10. Why does the orientation of the Big Dipper change with the seasons?

Figure 8.32 The Big Dipper changes its orientation in the sky throughout the year.

During Reading | Thinking Literacy

Taking Notes

A simple strategy for taking notes is to create a two-column chart. List important ideas, concepts, and terms in the left-hand column. Then write the key information or definitions related to those ideas, concepts, and terms in the right-hand column. A two-column chart provides a good study tool.

Rotation: Creating Day and Night

The North and South Poles mark the two ends of Earth's axis on the planet's surface. One complete spin of Earth on its axis is called a **rotation**. A rotation takes almost 24 h, with Earth moving at 1670 km/h towards the east at the equator. Earth's axis is tilted at an angle of 23.5° relative to the imaginary flat surface, or plane, along which Earth orbits the Sun. This is shown in Figure 8.33.

It is this daily rotation of Earth that creates day and night. On the side of Earth facing the Sun, it is daytime. Twelve hours later, that same point on Earth is pointing away from the Sun. This is midnight.

Viewed from above the North Pole, Earth spins counter-clockwise. This explains why the Sun always appears to rise in the east and set in the west no matter where you are in the world.

Although it might feel as though the Sun is the object that is moving while we watch from a seemingly stationary Earth, really it us spinning like a top around Earth's axis. Standing on Earth, we are carried eastward toward the Sun. We do not feel the motion of rotation because the rotation is relatively slow and the ground and air move with us. Instead, we see the Sun "rise." As Earth continues to spin, we are carried past the Sun until, later in the rotation, the Sun appears to disappear below the horizon, or set.

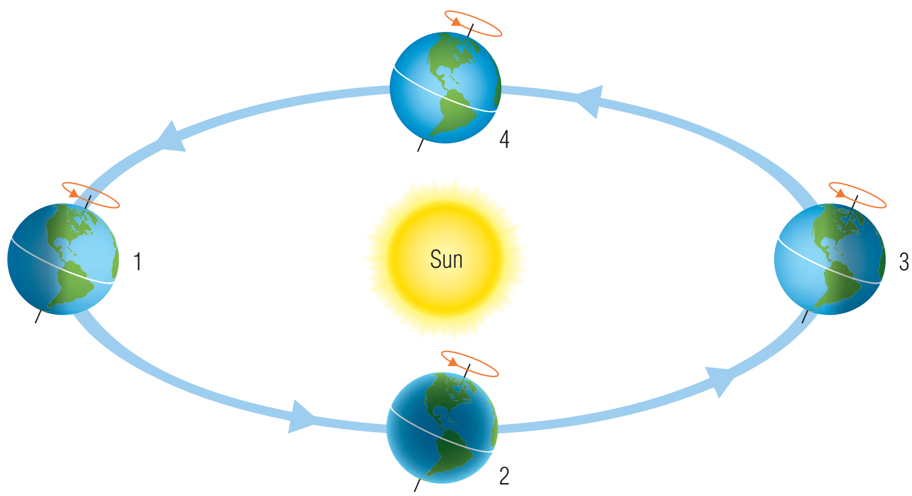


Figure 8.33 Earth rotates on its axis and revolves in its orbit around the Sun. When Earth's northern hemisphere is pointed away from the Sun, the season there is winter.

Revolution and Tilted Axis: Creating Seasons

Seasons occur in all parts of the world but differ from region to region. In the tropics near the equator, there are usually only two seasons: wet and dry. Other equatorial regions experience a monsoon season, hurricane season, hot season, or cool season. However, in northern and southern parts of the world, such as Canada and New Zealand, four seasons are generally recognized: spring, summer, autumn, and winter. When it is summer in Canada, it is winter in New Zealand. Six months later, it is New Zealand's turn to have the long warm days and short nights of summer while Canada goes into the season of short days and cold weather (Figure 8.34).

Changing seasons are the result of Earth's tilted axis and the planet's revolution around the Sun (Figure 8.33). A **revolution** is one complete orbit of Earth around the Sun, a journey of one year. The axis of Earth always stays at approximately the same tilt, regardless of the season. Earth's North Pole points almost exactly toward the star Polaris. This means that for a period during Earth's orbit around the Sun, the northern hemisphere is tilted toward the Sun. This creates summer in the northern hemisphere, with days lengthening as the Sun rises early and sets late. As Earth orbits to the far side of the Sun, the planet's axis is still pointed at Polaris, but the northern hemisphere now tilts away from the Sun. This creates winter in the northern hemisphere, with days shortening as the Sun rises late and sets early.

In spring and autumn, neither of Earth's hemispheres is more directed at the Sun than the other. This means that, for a time, days and nights are 12 h long everywhere on Earth.

(a)

(b)

Figure 8.34 Typical January weather in (a) Ontario, in the northern hemisphere; and (b) New Zealand, in the southern hemisphere

The Moon

The Moon is about one-sixth the mass of Earth. The two bodies are bound together by gravity. Like Earth, the Moon rotates on an axis. Over time, the Moon's period of rotation (the time to spin once) and period of revolution (the time to orbit once around Earth) have become equal. Every 27.3 days, the Moon rotates and revolves once. For this reason, the same side of the Moon always faces Earth.

Suggested Activity •
C20 Quick Lab on page 330

Phases of the Moon

The Moon is bright because it is reflecting the Sun's light. You know from seeing the Moon on different nights how the shape of its bright part changes daily. These various changes are referred to as the Moon's "phases." Although the changing appearance of the bright part of the Moon is a continuous process, eight main phases have been identified (Figure 8.35).

It is the Moon's revolution around Earth that creates the phases. One complete change of phases is called the lunar cycle. Many early cultures tracked time according to the lunar cycle. Some lunar calendars have 13 months in a year rather than 12 months.

The full moon occurs when Earth lies between the Sun and the Moon (though not usually exactly between or that would cause an eclipse, described below). In this position, with the Moon on one side of Earth and the Sun on the other, the entire illuminated side of the Moon faces Earth. Two weeks later when the Moon lies between Earth and the Sun, none of the sunlight reflected by the Moon can reach Earth. This is called a new moon, because over the next two weeks the Moon will become newly illuminated again.

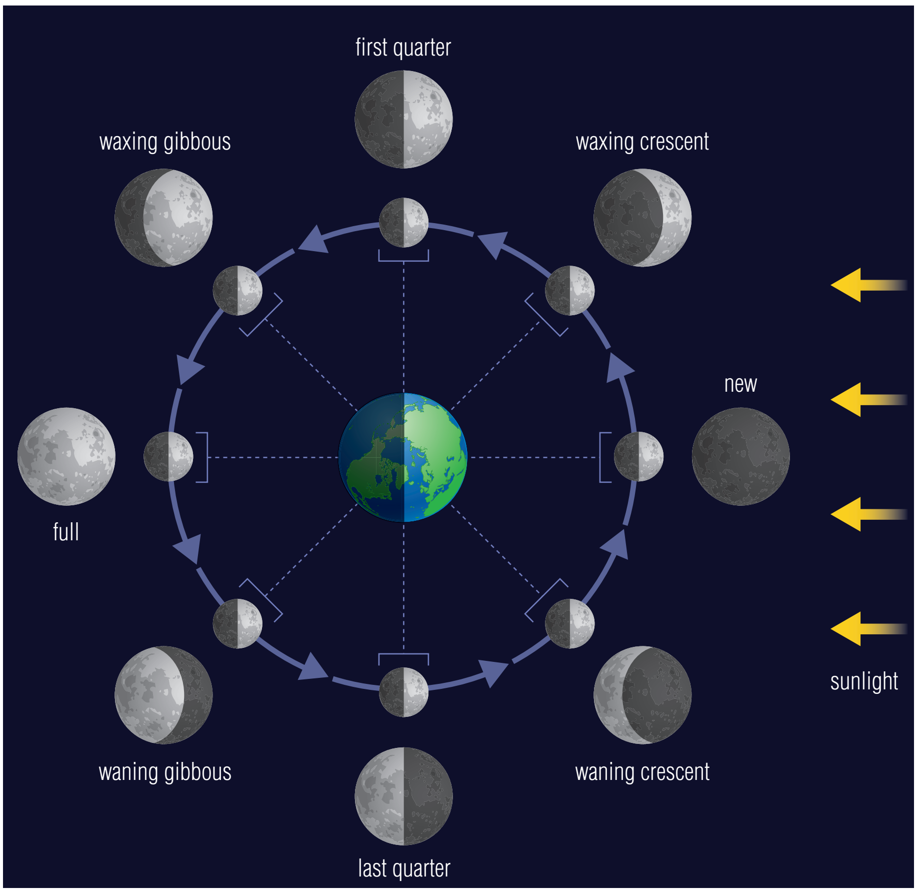


Figure 8.35 The phases of the Moon are shown as seen from Earth. The lunar cycle begins with a new moon, grows in size to a full moon two weeks later, and then gradually diminishes until the new moon begins again.

Learning Checkpoint

1. Earth rotates and revolves. Explain what each of these action means.
2. The axis of Earth is tilted. What is it tilted in relation to?
3. Explain why when it is summer in the northern hemisphere, it is winter in the southern hemisphere.
4. Why do we see only one side of the Moon at all times?
5. Sketch how the Sun, Earth, and the Moon are arranged on a night when we can see a full moon.

WARNING: If you are ever lucky enough to view a solar eclipse in person, be sure to watch it through a suitable filter or by projecting the Sun's image onto a screen. Never look at the Sun with the unprotected eye or you risk doing permanent damage to your vision.

Eclipses

Although the Sun is about 400 times the size of the Moon in diameter, both objects as seen from Earth appear to have the same size in the sky. The reason for this is that the Sun is also about 400 times farther from us than the Moon is. Because of this similar size appearance, when the Sun, the Moon, and Earth line up exactly, a partial or total shadow of one body is cast on another. Such overshadowing events are called "eclipses."

Solar Eclipse

A **solar eclipse** occurs when the Moon blocks the Sun's light to viewers on Earth. For a few minutes, some or all of the Sun seems to disappear. This happens when the Moon lies directly between Earth and the Sun. As Figure 8.36 shows, with the Sun shining behind it, the Moon casts a shadow over a small part of Earth.

Solar eclipses are of two main types. In a partial solar eclipse, the Sun is only partially blocked from our view by the Moon (Figure 8.37a). In a total solar eclipse, the Moon completely blocks out our view of the Sun (Figure 8.37b).

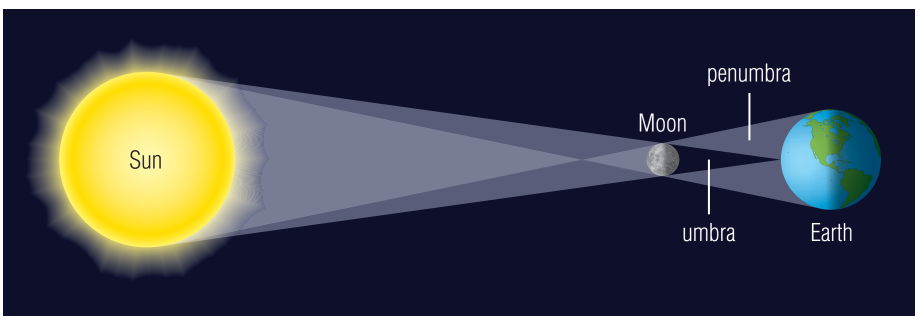


Figure 8.36 For a total solar eclipse to occur, the Moon must be aligned exactly between the Sun and Earth.

(a)

(b)

Figure 8.37 (a) Partial solar eclipse (b) Total solar eclipse

(a)

(b)

Figure 8.39 (a) Partial lunar eclipse. (b) Total lunar eclipse

Lunar Eclipse

A **lunar eclipse** occurs when Earth blocks out the Sun's light shining on the Moon, making the Moon briefly disappear, fully or partially. This happens when Earth lies directly between the Moon and the Sun, as shown in Figure 8.38. Observers on Earth see the Moon pass under Earth's shadow. The shadow cast across the Moon is circular because Earth is a sphere.

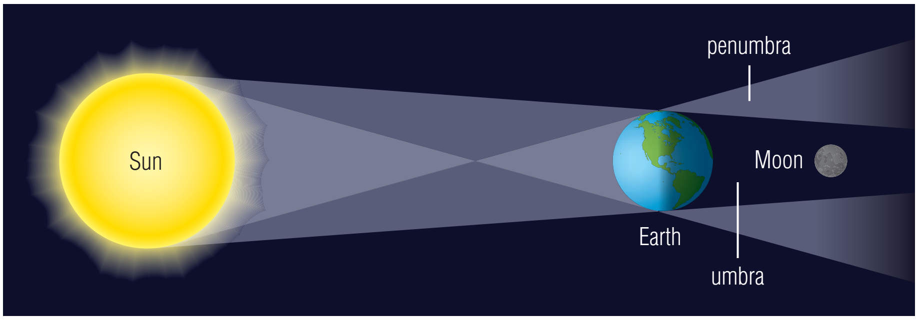


Figure 8.38 For a total lunar eclipse of the Moon, Earth must be aligned exactly between the Sun and the Moon.

As with solar eclipses, lunar eclipses are of two main types. In a partial lunar eclipse, the Moon is only partially blocked from our view by Earth's shadow (Figure 8.39a). In a total lunar eclipse, Earth's shadow darkens the entire Moon (Figure 8.39b).

Tides

Some first-time visitors to an ocean learn about tidal action the hard way. If they leave their shoes or a beach towel on the shore unattended, within an hour or so the level of the water can rise enough to soak the shoes and towel completely.

Tides are the alternate rising and falling of the level of the oceans every day. They are caused by the rotation of Earth in the presence of the Moon and, to a lesser extent, the Sun. The gravitational pull of the Moon and Sun on Earth's oceans and Earth itself causes the water bodies to bulge. As the oceans rise higher in one part, they fall in another. The pattern then reverses.

Figures 8.40 shows how the Moon causes a bulge in two places on Earth, both on the near side and on the far side. The bulge on the far side occurs because the Moon's gravitational pull is not as strong there. Earth is being pulled toward the Moon more than the water on the far side is. This creates the bulge on both sides of Earth at once. The two bulges result in two high tides and two low tides in coastal areas of Earth almost every day.

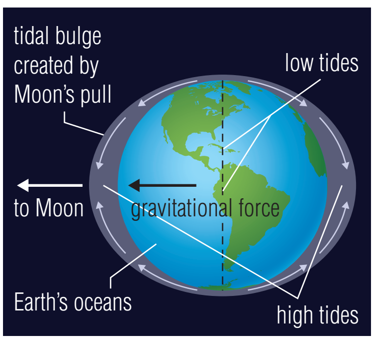


Figure 8.40 The effects of the gravitational field of the Moon on Earth's oceans causes a bulge on both sides of Earth, resulting in two tides per day.

The Bay of Fundy on the east coast of Canada is famous for having the largest vertical tidal range (the difference between high tide and low tide levels) in the world. In the open ocean, where the rise and fall of the water level is not affected by land, the daily vertical tidal range averages less than 1 m. By comparison, the Bay of Fundy creates a narrow, funnel-like channel that constricts the incoming water as the tide rises. As a result, the vertical tidal range in the bay can be as much as 17 m a day. Figure 8.41 shows the effects of these changing tide levels along the Fundy coast.

Take It ***Further***

Earth has several other kinds of motion besides rotation and revolution. One is called precession, which is the changing angle of the axis of rotation. Like the axis of a spinning top changing angle as the top moves across a table, so Earth's axis of rotation slowly changes angle. One complete cycle of precession takes 27 000 years. Find out more about Earth's precession. Begin your research at ***ScienceSource***.

(a)

(b)

Figure 8.41 New Brunswick's Bay of Fundy is well known for its large range between (a) high tide levels and (b) low tide levels.

C19 STSE *Science, Technology, Society, and the Environment*

Space Weather

The Sun's energy heats Earth and supports all life on the planet. At the same time, however, the Sun poses many challenges for Earth's inhabitants. The electrified gas that the Sun occasionally spews into space from its turbulent and explosive surface creates what astronomers call "space weather."

When solar storms occur, Earth is bombarded by showers of charged particles. Such events can destroy orbiting satellites (disrupting, for example, cellphone, television, and other communications systems) and burn out power grids that supply electricity to homes and businesses. Even the top of Earth's ozone layer, the part of the atmosphere that prevents harmful ultraviolet radiation from reaching the planet's surface, is greatly reduced when Sun activity sends out a blast of streaming particles.

1. ***ScienceSource*** Use the links provided at ***ScienceSource*** to read more about space weather and how sunspot activity and solar storms can affect humans and equipment. Make a consequence map, or write a news article or weather alert.

C20 *Quick Lab*

The Phases of the Moon

Have you ever noticed a full moon rising at sunset or setting at sunrise? Does it always happen this way for full moons? Why are there some times at night when the Moon is not visible and some times in the day when it is? Why does the Moon sometimes appear only as a crescent? In this activity, you will investigate these questions.

Purpose

To investigate what causes the phases of the Moon

Materials & Equipment

- bright light without a shade
- white Styrofoam spheres stuck on the end of a pencil (one per student)

Procedure

1. Students spread out, with enough room to hold their model Moon slightly overhead at arm's length and be able to rotate with the sphere held out. Each student is Earth.
2. The teacher, as the Sun, will make the room dark and stand in a central position holding a very bright, unshaded light overhead (Figure 8.42).

Figure 8.42 Step 2

3. Standing in one spot, each student rotates to a noon position. Students may discuss what the correct position for this is. Then, find the correct position for sunrise, sunset, and midnight. Compare with other students until there is agreement as to what this looks like in your model.
4. Stand so that it is midnight and hold up the model Moon at arm's length, high enough so that your head does not cast a shadow on the sphere.
5. Experiment by moving the model Moon to different locations around your head, always at arm's length. Observe the shadows that appear on the Moon. Discuss with other students what their observations are.
6. To model one month of the Moon's movement, hold out the Moon and turn counter-clockwise. Note the continuous change of the shadow on the Moon as seen from Earth. Discuss your observations with another student until you agree on what you are seeing.
7. One last time, follow the Moon through one month of phase changes, this time noting whether you are most likely to view each phase during the daytime or at night.

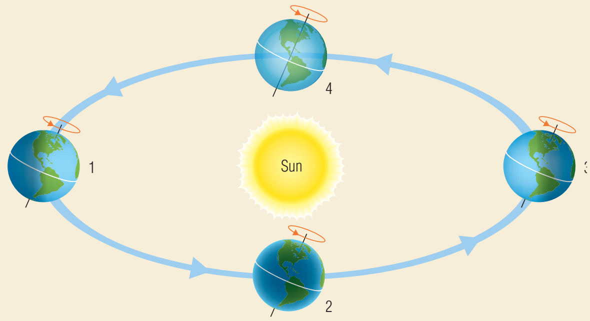
Questions

8. Does a full moon always rise at sunset and set at sunrise? Explain.
9. Draw three phases of the Moon that are most likely to be seen (a) during the daytime and (b) at night.
10. Does the amount of sunlight striking the Moon change during the month (not counting eclipses)? Explain.
11. Why does the amount of sunlight reflected from the Moon to Earth change during a month?
12. ***ScienceSource*** Research the names for the different phases.

8.3 CHECK and REFLECT

Key Concept Review

1. How much time does one rotation of Earth take?
2. How much time does one revolution of Earth take?
3. From Earth, why does the Sun appear to be rising in the east and setting in the west?
4. Referring to the figure below, identify in which position of Earth it would be:
   (a) summer in the northern hemisphere
   (b) winter in the southern hemisphere
   (c) autumn in the northern hemisphere



Question 4

5. Define each of the following astronomical phenomena, and sketch the positions of Earth, the Sun, and the Moon to illustrate your definition.
   (a) solar eclipse
   (b) lunar eclipse

Connect Your Understanding

6. Do you agree or disagree with the statement "A total eclipse of the Moon by Earth can happen only during a full moon"? Justify your answer using a diagram.
7. Most coastal areas on Earth experience two high tides and two low tides a day.
   (a) Describe the function of the Moon in generating these tides.
   (b) Predict how the tides would be affected if the Moon orbited Earth closer than it does now.
8. When we view the nighttime sky, the positions of the stars constantly change except for Polaris, the North Star.
   (a) What causes the apparent motion of the stars in the night sky?
   (b) Why does Polaris appear to stay in a constant position in the sky?
9. Why is the Moon not shown on star charts?
10. Earth can completely eclipse the Moon, but the Moon cannot completely eclipse Earth. What conclusion can you draw from this fact about the relative sizes of two bodies?
11. "Eclipse chasers" are people who make a hobby of travelling around the world for the opportunity to watch solar eclipses first-hand, especially total solar eclipses. Explain:
    (a) how scientists are able to forecast when solar eclipses will occur and from what positions on Earth they can be seen
    (b) why no one observing a partial or total solar eclipse should ever do so by looking at the event directly

Reflection

12. Many aspects of the interrelationship between Earth, the Sun, and the Moon were discussed in this section. List two questions you still have about any of these aspects.

For more questions, go to ***ScienceSource***.

Great CANADIANS in Science Julie Payette

Figure 8.43 Canadian astronaut Julie Payette working aboard the International Space Station in 1999

Many Canadian travellers take maple syrup and crests of their favourite hockey teams with them to offer as gifts on a trip outside the country. So, when Julie Payette was packing for a trip she was about to make out of the country — in fact, off the planet and all the way to the International Space Station — she decided to take those gifts along, too.

In May 1999, Payette was part of the crew on NASA's space shuttle *Discovery,* which docked with the International Space Station. The space station was still in its early stages of assembly while it orbited Earth at 400 km. Working as a mission specialist, Payette had a range of duties to fulfill during the more than nine-day space flight. Chief among those was helping to repair an electrical system on the space station, coordinating and supervising an 8-h space walk, operating the robotic Canadarm, and doing maintenance on the space station's photography and recording equipment.

Figure 8.44 Julie Payette in training to operate a robotic servicing system used on the International Space Station

For the then 36-year-old astronaut, who is from Montreal, Quebec, the opportunity to go into space was something she had set her sights on since childhood. Payette credits a belief in hard work and a "Dare to dream" philosophy as helping her reach that goal. Payette's list of achievements includes speaking two languages fluently (French and English), four languages conversationally (Russian, Italian, Spanish, and German), earning university degrees in electrical and computer engineering, being selected from among more than 5300 applicants in 1992 to become an astronaut with the Canadian Space Agency, and obtaining a commercial pilot licence and then certification as a jet pilot and as a deep-sea diving suit operator.

As part of the *Discovery* mission, Payette became not only the first Canadian to participate in assembling the International Space Station but also the first Canadian to board the station — and, let it not be forgotten, the first astronaut to arrive at the space station bearing maple syrup and a Montreal Canadiens hockey crest.

Questions

1. What duties did Julie Payette have in her role as mission specialist during her flight to the International Space Station in 1999?
2. *ScienceSource* Use the Internet to find out about Julie Payette's second mission to the International Space Station, aboard the space shuttle Endeavour in 2009.

Science in My FUTURE Robotics Engineer

Figure 8.45 Robotics engineers design and build many robotic systems for the space industry. Examples include Canadarm2 and Dextre, whose official title is the Special Purpose Dexterous Manipulator.

Dextre may not be able to play the piano or type text messages, but the "robotic handyman" at the International Space Station comes by its name honestly. Dextre (pronounced Dexter) is short for dexterous, which means having the ability to manipulate something manually. What Dextre does well is use its two long robotic arms and two-fingered hands to make delicate repairs and installations on the outside of the space station. For this capability, Dextre — designed and built in Brampton, Ontario — has become famous.

Canada is a leader in robotics technologies. The space industry employs many people who work in this field. Robotics are automated mechanical systems capable of performing many tasks that a person could. In space, which is an extremely high-hazard environment for people to work in, robotics are vital.

This is where robotics engineers come in. Robotics engineers design, test, and build robotic systems to carry out specialized tasks in specific settings. In addition to having a thorough understanding of how mechanical systems work, a robotics engineer must have the knowledge to create computer programs that install and operate robotics systems. He or she must also excel at problem-solving. Having a creative and imaginative mind is a beneficial quality, too.

To become a robotics engineer, a person first requires a bachelor's degree or higher in engineering. Robotics technologies used in the space industry draw from many different areas of engineering, including software, systems, mechanical, electrical, and electronics. Some universities and colleges have even developed robotics engineering degrees.

Working closely with robotics engineers are robotics technologists and technicians. Many colleges and technical institutes offer one- to three-year programs that teach practical and applied skills in such jobs as robotics planning, testing, manufacturing, inspecting, and repairing.

Questions

1. Name three qualities that someone interested in becoming a robotics engineer would benefit from having.
2. *ScienceSource* Use the Internet to learn more about the education requirements to become a robotics enginer, technologist, or technician.

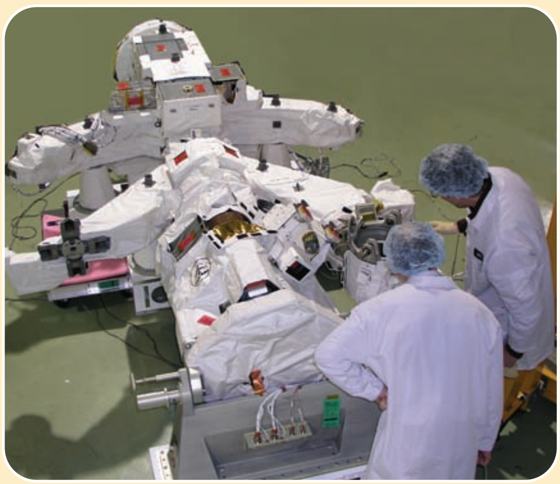


Figure 8.46 Demand for robotics engineers will continue to grow as demand for robotics systems onboard space craft grows.

8 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

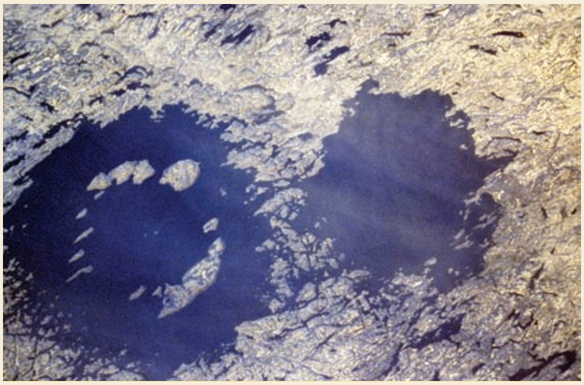
k Knowledge and understanding t Thinking and investigation
c Communication a Application

Key Concept Review

1. Define a protostar. k
2. What is the relationship between the mass of a star at its birth and the life span of the star? k
3. In terms of mass, what kind of star is the Sun: low, medium, or high? k
4. Name the process occurring in the core of the Sun that gives it its ability to shine. k
5. High mass stars end their existence in an explosion that can produce one of two types of results. What are those two results? k
6. What is convection, and how does this process help the energy produced in the core of the Sun make it to the outside? k
7. Why does a prominence take on the shape of a huge arc on the surface of the Sun? k
8. What is the solar wind? k
9. How do astronomers believe the Moon was formed? k
10. How have astronomers used asteroids to estimate the age of the solar system? k
11. What is a comet? k
12. Explain the difference between the terms revolution and rotation in terms of Earth's motion. k
13. (a) What causes the changing phases of the Moon? k
    (b) How many main phases of the Moon are there? k
14. List the three key properties of stars used to construct a Hertzsprung-Russell diagram. k

Connect Your Understanding

15. Suppose you can see two stars of equal brightness in the night sky. One star appears to be yellow in colour, and the other star appears to be blue. Which star is closer to Earth? Explain your answer, making reference to the Hertzsprung-Russell diagram in Figure 8.11 on page 301. t
16. When an asteroid strikes Earth, it can cause great damage. A pair of asteroids simultaneously crashed into the Canadian Shield on the east side of Hudson Bay about 290 million years ago as shown in the image below. Suggest how it might have happened that the two asteroids crashed at the same time. t

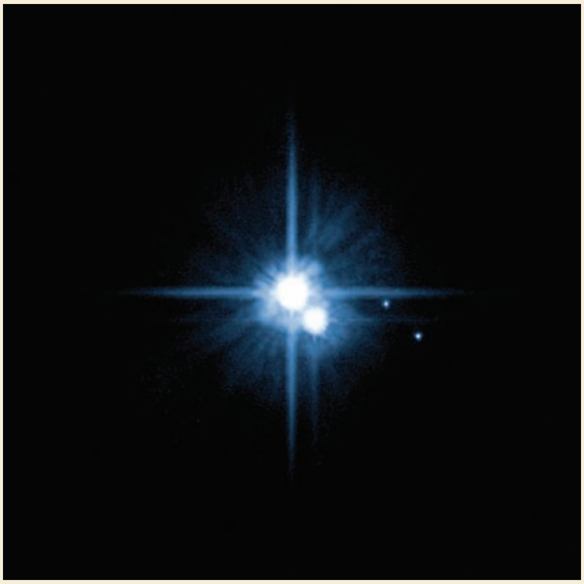


Question 16

17. The four gaseous outer planets are by far the largest planets in the solar system. Why did they grow much larger than the four rocky inner planets? t
18. Explain how, if you see a comet, you would know in which direction the Sun lies. t

19. Suppose a gaseous planet half the size of Saturn were discovered. Where in the solar system do you think it would be located? Give a reason for your answer. t

20. For decades, Pluto was classified as being the ninth planet in the solar system. It even has three moons, as shown in the image below. Today, Pluto is classified as a minor planet. Recall the characteristics of the eight planets, and list at least two reasons supporting Pluto's reclassification as a minor planet and two reasons against its reclassification. a



Question 20 Pluto and its moons, Charon, Nix (in the middle), and Hydra (far right).

21. Does summer occur because Earth moves closer to the Sun or because the part of Earth experiencing summer receives more sunlight? Make a sketch to illustrate your answer. c

22. Compare the positions of the Sun, Earth, and the Moon during a solar eclipse to their positions during a lunar eclipse. t

Reflection

23. The following words are often used in explanations and discussions about star formation and evolution: nursery, birth, life cycle, and death. Do you think that the use of these words provides a reasonable analogy or not? Explain your thoughts on this. c

After Reading

Thinking Literacy

Reflect and Evaluate

Work with a partner to list all the strategies you know and have learned for determining or finding important ideas. Create a tip sheet for other students in the class on how to find important ideas. Exchange your tips with another pair of students and then post your sheet in the classroom, with the teacher's permission.

Unit Task Link

The solar system consists of four rocky planets, four gas giants, and many other objects, each following a path around the Sun and each travelling at a different speed. Millions of asteroids, comets, and meteoroids also travel through the solar system. Explain how the relative speeds of Mars and Earth, as well as the presence of so many other bodies moving between the two planets, pose a challenge for sending a space probe from Earth to Mars.