TOPIC 7 The Solar System Up Close

Everything in the solar system is under the influence of the Sun's gravity. In a sense, the solar system is the Sun's family. Astronomers have learned more about the solar system in the last few decades than was previously known throughout human history. This knowledge came from our ability to send spacecraft to the Sun, the planets, and their moons. As you learned in Topic 6, computers and rockets helped put satellites and spacecraft into Earth's orbit and keep them there. These technologies have also enabled us to send spacecraft throughout the solar system. Topic 7 looks at some of the things these spacecraft have shown us about our solar system — up close!

DidYouKnow?

When the solar wind reaches Earth's magnetic field, some of its particles spiral down the magnetic field and enter the atmosphere near the Poles. Reactions with particles in the atmosphere produce the aurora Borealis (the northern lights) and the Aurora Australis (the southern lights).

The Sun

The Sun is a huge globe of mostly hydrogen, the lightest of gases. It is about 1.4 million km in diameter, almost 110 times the diameter of Earth. The Sun is so hot that the gas glows. It is the light from this gas that speeds through space to reach and warm Earth.

The surface of the Sun constantly writhes and churns. Spectacular solar prominences, such as the one in Figure 5.50, are streamers of glowing gas that arch into space. Some regions on the Sun are cooler and therefore appear to be darker than their surroundings. These are known as Sun spots. Near them, violent outbursts called solar flares erupt, sending streams of high-energy subatomic particles into space.

This outflow of particles is called the **solar wind**. The solar wind defines the boundaries of the solar system. If a location in space "feels" the solar wind, then it is considered to be in the solar system. Earth's magnetic field protects us from the harmful effects of the solar wind.

Figure 5.50 This image of the Sun, including a huge prominence, was captured by instruments on *Skylab*, a U.S. space-based laboratory.

The Sun's own gravity has compressed its hydrogen so much that the temperature at the centre of the Sun is 15 million degrees Celsius. This is high enough for a kind of nuclear reaction (fusion) to take place. About 600 t of hydrogen are converted into helium per second. This is how energy is released from the Sun.

DidYouKnow?

Galileo observed the Sun through his small telescope. He held the objective lens over a candle flame until it was covered with soot, which enabled him to make out details on the Sun's surface. Unfortunately, the Sun is unsafe to observe through such a poor filter and Galileo went blind during his later years. You should never look directly at the Sun without a proper solar filter.

Travelling Through the Solar System

Since Galileo's time, people have been curious about what the planets were like. By the middle of the twentieth century, our best Earth-based telescopes had imaged the larger features of most of the planets and discovered several of their moons. However, astronomers knew the only way to really learn about the planets and their moons was to see them up close. Spacecraft finally enabled them to do this.

The Moon

The first other world seen up close was the Moon. The Moon is not a planet, but it is the first place people went to in the solar system. The United States set a target to land astronauts on the Moon by 1970. On July 17, 1969 two men did land on the Moon — Neil Armstrong and Edwin Aldrin. You will learn more about this spectacular event in Topic 8.

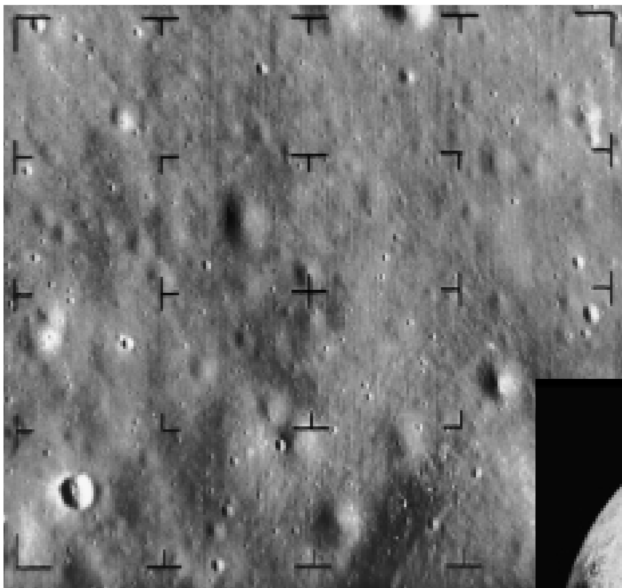


Figure 5.51 Scientists needed to find out whether the surface of the Moon was smooth enough for a spacecraft to land on before setting people down on its surface. The Americans crash-landed a series of satellites (the Ranger series), which took pictures until the last moment before they crashed. *Ranger 8* took this picture at an altitude of 11 km, about 5 s before it crashed in the Sea of Tranquility about 2°N of the *Apollo 11* landing site. The picture covers a distance of about 2 km across and features as small as 4 m can be seen.

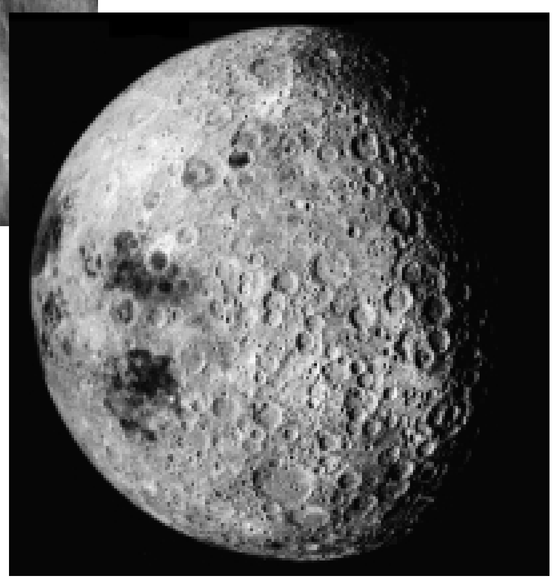


Figure 5.52 The former Soviet Union was also interested in the Moon. They flew satellites around the far side of the Moon and photographed craters never seen before by humans The Moon rotates in the same time it takes for it to go around Earth. Because of this, the lunar far side is never visible from Earth. This is an *Apollo* picture of the far side.

The Planets

All the planets differ from one another in size, motion, composition, density, and temperature. No two are exactly alike, although some share a few similar features. For example, the **inner planets** — Mercury, Venus, Earth, and Mars — are sometimes called the terrestrial planets, because of their terrestrial, or rocky, composition. Jupiter, Saturn, Uranus, and Neptune — the **outer planets** — are similar because of their gaseous composition. The next Find Out Activity will help you learn more about the planets.

Find Out ACTIVITY

Planetary Profiles

Here's your chance to become an expert about the planets in the solar system. Find out about one planet and see what kind of technological tools astronomers used to find out about them. Share your knowledge with your class.

Procedure ✴ Initiating and Planning ✴ Communication and Teamwork ✴ Performing and Recording

1. As a class, brainstorm the types of facts that you should find out about the planets.
2. Organize into nine groups. Your teacher will assign each group one planet. Your group will become experts on the planet you are given. Your job is to develop a profile of your planet that describes its overall characteristics, the features that make it unique. Find as many little-known facts as you can.
3. With your group, brainstorm resources you might use to research your planet. You can start by using the information provided in this book. Then consider using the Internet, the library, and subject experts at a local university or college.
4. As a group, organize the information you have gathered and prepare a class presentation. Use a variety of media and formats in your presentation, such as audio-visual aids, computer simulations, performance, flipcharts, computerized database or spreadsheets, and scale models. As well, prepare a one-page summary of your planet profile to distribute to the rest of the class at the end of your presentation. Do not forget to list your sources of information.

What Did You Find Out? ✴ Analyzing and Interpreting

Using your group's research and the information you received from the presentations of all the other expert groups, answer the following questions in your Science Log. When you have finished, discuss your answers with the rest of the class.

1. Which planets are most unlike Earth? Explain your conclusions.
2. Which planets are most similar to Earth? Explain your conclusions.
3. What pattern do you notice about the surface temperatures on the planets?
4. Venus is considered Earth's twin, yet we would probably not survive on Venus. Why?
5. What is the main difference between the inner and the outer planets?
6. Why does Venus have a higher surface temperature than Mercury?
7. Scientists are debating whether or not to remove Pluto from the list of major planets. Why?

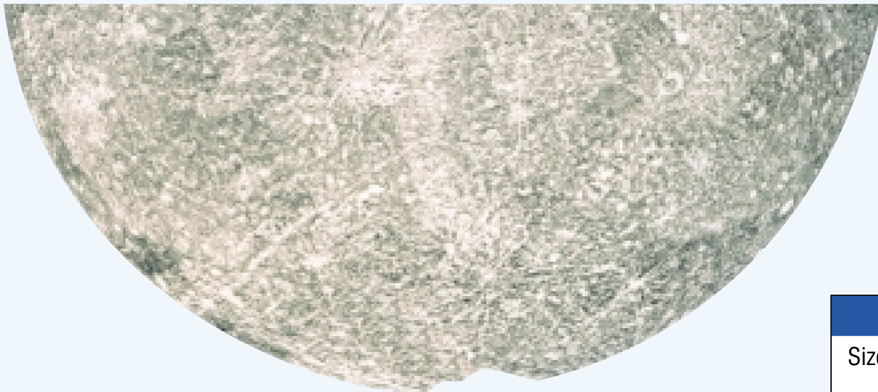
INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

The NASA web site contains a lot of information that can help you with your research for Find Out Activity: Planetary Profiles. Go to the web site above, and click on Web Links to find out where to go next.

Data Cards for the Inner Planets

Mercury



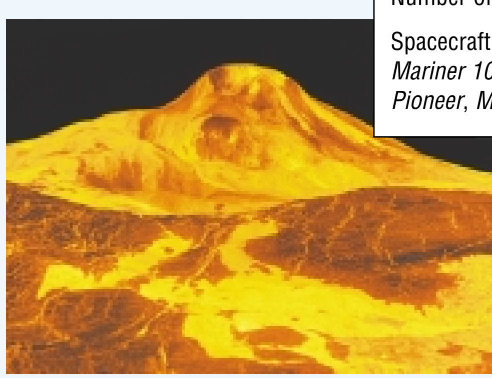
Mercury has a thin crust and an inner solid layer, both composed of silicate rock. Beneath these is a huge iron-rich core, which makes up 80 percent of the planet's mass. Its very thin atmosphere consists of trace amounts of sodium and phosphorus that the fierce daytime surface temperatures (as high as 430°C) "boil off" the planet's crust. Night temperatures drop to –180°C. About 60 percent of Mercury's surface is covered by craters. The remaining area is relatively smooth, suggesting evidence of past lava flows from volcanic activity.

Mercury
Size (Earth-diameters): 0.38
Distance from Sun (AU): 0.39
Mass (Earth-masses): 0.06
Density (Earth-density): 1.0
Average Surface Temperature (°C): 180
Rotation Period (days): 58.6
Orbital Period (years): 0.24
Number of Moons: 0
Spacecraft Observation: *Mariner 10*

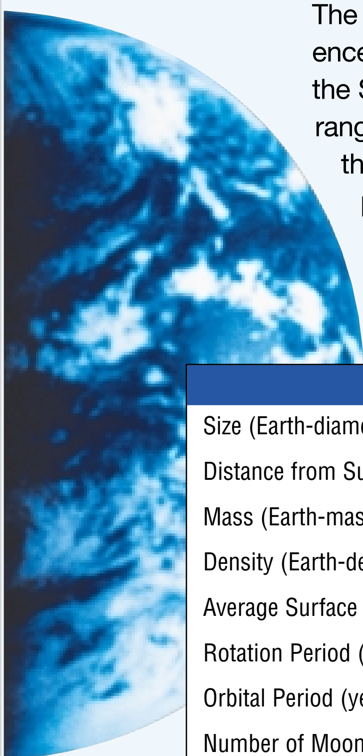
Venus

Venus is enveloped by a thick atmosphere, 96 percent of which is carbon dioxide gas, 3.5 percent nitrogen, and the rest small amounts of other chemicals, including sulfuric acid rain. It is this atmosphere that accounts for Venus having the highest average surface temperature of any of the planets. The carbon dioxide is very efficient at trapping the solar radiation that falls on the planet's surface. A thin crust and rocky mantle surround Venus's semi-solid iron-nickel core. Radar mapping from Earth and space probes have revealed large meteorite craters and extinct volcanoes. A particularly distinctive feature of Venus is that it rotates from east to west, rather than from west to east, as do most of the other planets and the Sun.

Venus
Size (Earth-diameters): 0.95
Distance from Sun (AU): 0.72
Mass (Earth-masses): 0.82
Density (Earth-density): 0.95
Average Surface Temperature (°C): 460
Rotation Period (days): 243
Orbital Period (years): 0.62
Number of Moons: 0
Spacecraft Observation: *Mariner 2* and *Mariner 10*, *Venera 7* and *Venera 9*, *Pioneer*, *Magellan*



Earth



The main characteristic that sets Earth apart from the other planets is the presence of diverse life forms and large quantities of liquid water. Its distance from the Sun, in combination with its particular atmospheric make-up, produces a range of suitable surface temperatures for this to happen. Nitrogen dominates the atmosphere (78 percent). Life-sustaining oxygen (21 percent) has been present only for the past 2 billion years, originating from bacterial processes during life's early development. Water vapour, carbon dioxide, and other trace gases account for the remaining 1 percent. The thin crust is composed of rocks, some of which are 3.9 billion years old.

A rocky mantle surrounds a molten outer layer and solid inner iron-nickel core.

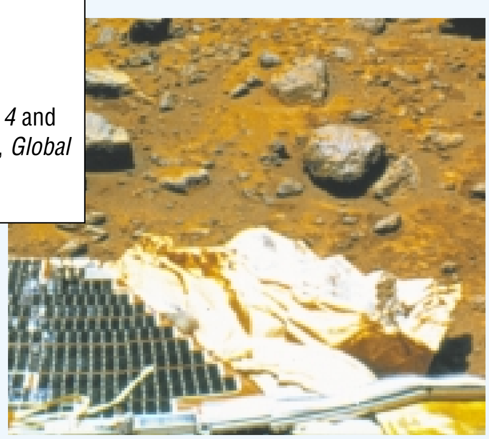
Earth's Moon orbits the planet in about a one-month period. At the same time, it also completes one rotation on its axis. The Moon's surface is significantly cratered. It also has large smooth areas that indicate past lava flows. Recent evidence shows water ice in the polar regions. Moon rocks brought back to Earth by *Apollo* astronauts are 4.5 billion years old. Compared with Earth, the Moon is much less dense, and its atmosphere is negligible.

Earth
Size (Earth-diameters): 12 756 km
Distance from Sun (AU): 149.6 million km (1 AU)
Mass (Earth-masses): 5.98×10^{24}kg
Density (Earth-density): 5.52g/cm^3
Average Surface Temperature (°C): 14
Rotation Period (days): 23h 56m
Orbital Period (years): 365.25d
Number of Moons: 1
Spacecraft Observation: *Galileo*, *Cassini.*

Mars

Mars
Size (Earth-diameters): 0.53
Distance from Sun (AU): 1.52
Mass (Earth-masses): 0.11
Density (Earth-density): 0.71
Average Surface Temperature (°C): –50
Rotation Period (days): 1.03
Orbital Period (years): 1.88
Number of Moons: 2
Spacecraft Observation: *Mariner 4* and *Mariner 9*, *Viking 1* and *Viking 2*, *Global Surveyor*, *Pathfinder*, *Odyssey*

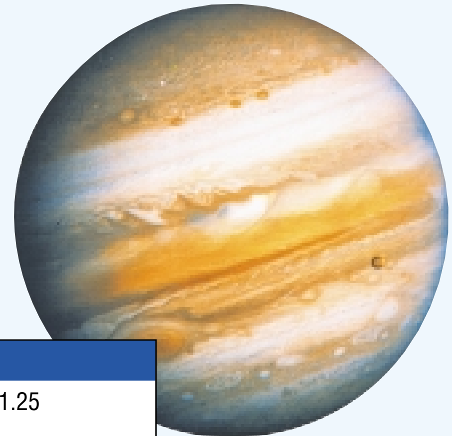
Reddish-orange in colour because of iron oxides in the surface material, Mars is under intense scrutiny from Earth. It has polar icecaps and surface features such as valleys, canyons, volcanoes, and craters. As on Venus, the atmosphere is composed mainly of carbon dioxide (95 percent), but is much thinner. Mars's distance from the Sun reduces the amount of solar energy falling on its surface, so temperatures can be very low, especially during the Martian night. The atmosphere's other parts are nitrogen (2.7 percent) and trace amounts of argon, oxygen, and water vapour. Robot probes like *Pathfinder* have explored the surface of the planet and recorded detailed images of the dust storms that are sometimes visible from Earth. An icy permafrost is present on the thin crust. Underneath, a rocky mantle surrounds a solid core.



Data Cards for the Outer Planets

Jupiter

Giant Jupiter is 2.5 times the mass of all the other planets combined. At its centre is a rocky core about twice the size of Earth. The rest of the planet consists mainly of hydrogen in various states. Solid hydrogen forms an inner mantle, surrounded by a liquid hydrogen and helium outer mantle. No solid crust is present. Instead, the surface features visible from Earth are shapes in the atmosphere, such as the Great Red Spot. Hydrogen is the main constituent of the atmosphere (90 percent), followed by helium (almost 10 percent). Trace amounts of methane, ammonia, and water vapour produce colourful effects in the distinctive cloud bands, formed as a result of Jupiter's rapid rotation. A narrow dust ring encircles the planet. It is composed of particles emitted from active volcanoes on Io, one of Jupiter's 17 moons. Scientists believe that the moon Europa may have oceans of liquid water beneath frozen surface ice.

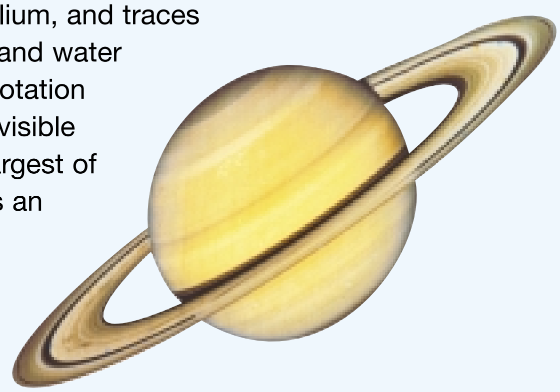


Jupiter
Size (Earth-diameters): 11.25
Distance from Sun (AU): 5.20
Mass (Earth-masses): 318
Density (Earth-density): 0.24
Average Surface Temperature (°C): –150
Rotation Period (days): 0.41
Orbital Period (years): 11.86
Number of Moons: 17
Spacecraft Observation: *Pioneer 10* and *Pioneer 11*, *Voyager 1* and *Voyager 2*, *Galileo, Cassini*

Saturn

Saturn
Size (Earth-diameters): 9.45
Distance from Sun (AU): 9.56
Mass (Earth-masses): 95
Density (Earth-density): 0.13
Average Surface Temperature (°C): –180
Rotation Period (days): 0.44
Orbital Period (years): 29.42
Number of Moons: 18
Spacecraft Observation: *Pioneer 11*, *Voyager 1* and *Voyager 2*, *Cassini*: (2004 expected arrival)

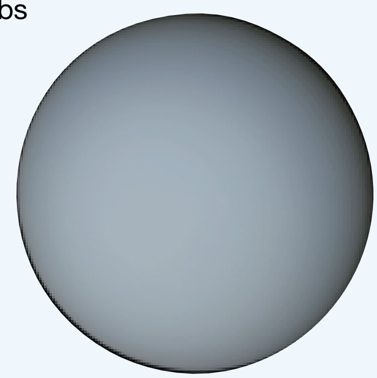
The distinctive ring system of Saturn, a large yellowish planet, is composed of ice-covered rock fragments and dust. Although colder than Jupiter, Saturn has a structure that is similar to its large neighbour: a rock and ice core, solid hydrogen inner mantle, liquid hydrogen outer mantle, and atmosphere of 94 percent hydrogen, 6 percent helium, and traces of methane, ammonia, and water vapour. Saturn's rapid rotation produces cloud bands visible from Earth. Titan, the largest of Saturn's 18 moons, has an atmosphere.



Uranus

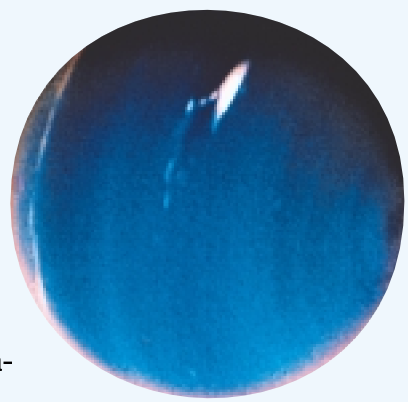
Uranus
Size (Earth-diameters): 4.01
Distance from Sun (AU): 19.22
Mass (Earth-masses): 15
Density (Earth-density): 0.24
Average Surface Temperature (°C): –210
Rotation Period (days): 0.72
Orbital Period (years): 83.75
Number of Moons: 21
Spacecraft Observation: *Voyager 2*

Uranus's rocky core and mantle of ice, ammonia, and methane are surrounded by a generally featureless atmosphere. That atmosphere is made up of 85 percent hydrogen and 12 percent helium. It is the 3 percent methane that absorbs red light and makes the planet seem predominantly blue. Uranus has a ring system consisting of eight relatively narrow bonds. Most interesting, however, is the fact that Uranus rotates on an axis tilted 90° to the plane of the solar system. Additional moons continue to be discovered.



Neptune

Almost a twin of Uranus, Neptune has the same internal structure as its slightly larger neighbour and a very similar atmosphere: 85 percent hydrogen, 13 percent helium, and 2 percent methane. A ring structure and a Giant Dark Spot were discovered by the space probe *Voyager*. One of Neptune's eight moons, Triton, has the lowest measured temperature in the solar system, –235°C.

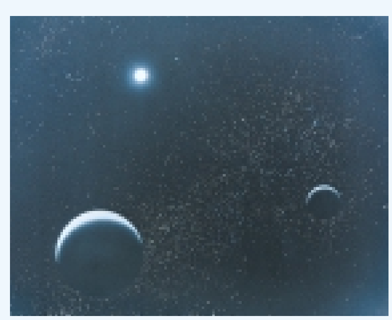


Neptune
Size (Earth-diameters): 3.88
Distance from Sun (AU): 30.11
Mass (Earth-masses): 17
Density (Earth-density): 0.32
Average Surface Temperature (°C): –220
Rotation Period (days): 0.67
Orbital Period (years): 163.73
Number of Moons: 8
Spacecraft Observation: *Voyager 2*

Pluto

Pluto
Size (Earth-diameters): 0.18
Distance from Sun (AU): 39.5
Mass (Earth-masses): 0.002
Density (Earth-density): 0.20
Average Surface Temperature (°C): –230
Rotation Period (days): 6.4
Orbital Period (years): 248.03
Number of Moons: 1
Spacecraft Observation: (none as of 2001)

Because Pluto is so far away, very little information is known about it. Its orbit is tilted to the plane of the solar system by 17° and it is elongated enough to put Pluto, at times, closer to the Sun than Neptune. Like Venus, Pluto has retrograde rotation. It spins in the opposite direction to its direction of revolution. A "best guess" for Pluto's structure is that it has a large rocky core, an ice mantle, and a water and methane ice crust. Pluto's moon, Charon, is nearly as large as Pluto itself. Some scientists speculate that Pluto and Charon are examples of large debris left from the formation of the solar system.



INQUIRY INVESTIGATION 5-H

SKILLCHECK
- Initiating and Planning
- ✷ Performing and Recording
- ✷ Analyzing and Interpreting
- Communication and Teamwork

Ecosystems and Stability

Of all the planets, it is most likely that humans will visit Mars, because Mars is the planet most like Earth. A human expedition to Mars would be a two-year round trip. Inside the spacecraft, the astronauts would be living in a biologically closed system, in which no matter enters or leaves. In this investigation, you will see how difficult it is to maintain a partially closed system. Imagine how hard it would be to keep a closed system stable for two years in space!

Question

How can you maintain a partially closed ecosystem for an extended period?

Hypothesis

Write an hypothesis about why it is hard to keep a small ecosystem stable for a long period of time.

Safety Precautions

Be careful when cutting the plastic pop bottle.

Apparatus

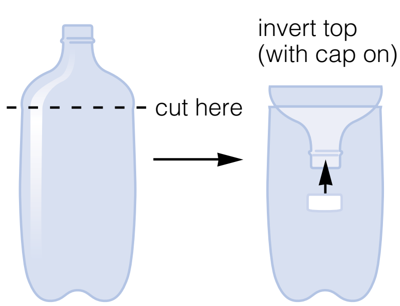
utility knife

Materials

2 L clear plastic pop bottle with its lid
aquarium water or dechlorinated tap water
sand or aquarium gravel
water plant (any type)
soil
land plant (any type)
snail
clear tape
nail (for poking)

Procedure

1. Cut the pop bottle as shown.
2. Make small holes in the cap and leave the cap on.



3. The bottom of the bottle is your "aquarium." Fill it with water and pour some sand or gravel in the bottom. Use aquarium water or dechlorinate tap water.
4. Anchor the water plant to the bottom of the bottle.
5. Invert the top of the bottle, fill it with sand and soil, and plant the land plant in it. Set the bottle top on the bottom and fasten it with tape.
6. Add a tiny snail in the water, if you want an animal in your ecosystem.
7. When you water your land plant, let the water filter to the plant below. **Monitor** the system over as long a period as you can. Once every few days, **observe** your ecosystem for evidence of dead plant matter and check to see if your snail is still alive. Try for one month if possible!

Analyze

1. Suggest reasons for any changes you see over the time period.
2. Did your system stay stable for a long time and suddenly crash? Why might this occur?
3. Your system isn't closed. What changes would you have to make to close it?

Conclude and Apply

4. Like the snail in your system, astronauts will depend upon the ecosystem within their spacecraft to survive. Describe some of the things that NASA's engineers will have to keep in mind when they design closed spacecraft ecosystems to keep astronauts alive.

PROBLEM-SOLVING

INVESTIGATION 5-I

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Mars Colony

It is possible that humans will visit Mars in your lifetime. There would be many challenges in designing a habitat that would enable humans to survive on Mars.

Challenge

Design a living habitat that is small enough to be transported to Mars. Every kilogram of mass that goes to a planet requires energy (and money) to get it there. The habitat must keep a group of six astronauts alive during a two-month stay on Mars.

Design Specifications

A. Your design must take into account the actual conditions of Mars. This means you will have to conduct research to find out what Mars is like.

B. The weight of your Mars habitat (and of the spacecraft) affects the trajectory that the spacecraft must take to Mars. Weight also affects how it will land and how it will return to Earth. Your design needs to include the trajectory to Mars, how the spacecraft will land, and how it will return.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

The *Mars Pathfinder* mission provided us with some three-dimensional images that document Mars's rough terrain. Take this rough terrain into account while designing your Mars colony. Go to the web site above, and click on Web Links to find out where to go to view some Martian surface images.

Plan and Construct

1. Research those characteristics of Mars that will affect how you need to design your living habitat (for example, temperature, atmosphere, gravity).

2. Create a display of your Mars habitat. It can be a model (paper, cardboard, balsa, etc.), drawing, computer presentation, or anything else that conveys your ideas to your classmates.

Evaluate

1. Analyze all the groups' design habitats. Make a list of the things that must be considered when designing a Mars habitat.

2. If you could design another Mars habitat, what would you change about your design?

3. During your research, you learned about Mars's physical characteristics. Why is it most likely that humans would attempt to colonize Mars instead of another planet in the solar system?

Skill FOCUS

For tips on problem-solving, turn to Skill Focus 7.

Exploring the Outer Planets

In the late 1970s NASA didn't have (and still doesn't have) a booster rocket powerful enough to send a heavy spacecraft to the faraway outer planets. So two spacecraft, *Voyager 1* and *Voyager 2*, were designed, built, and sent to the edge of the solar system with gravitational assists from the planets themselves.

They had different trajectories so that *Voyager 1* arrived at Jupiter first, in 1979. Four months later, *Voyager 2* arrived at Jupiter, the largest planet in the solar system. These spacecraft would travel next to Saturn, and *Voyager 2* next traveled to Uranus and Neptune. Neither *Voyager* spacecraft was able to visit Pluto.

DidYouKnow?

Two small spacecraft, *Pioneer 10* and *Pioneer 11*, were launched to Jupiter as a preparation for the *Voyager* missions to follow. *Pioneer 10* gave us our first close-up look at the Jovian system and *Pioneer 11* went to Saturn as well. They were smaller than the *Voyager* craft that followed them to the outer planets. The *Pioneers* acted as advance scouting missions.

These craft have ended their missions (*Pioneer 10* in 1997 and *Pioneer 11* in 1995). Both are headed out of the solar system.

Figure 5.53 The spacecraft that could! Each *Voyager* spacecraft flew almost 12 billion km from Earth to the edge of the solar system. They are travelling at 16–17 km/s, (58 000–61 000 km/h).

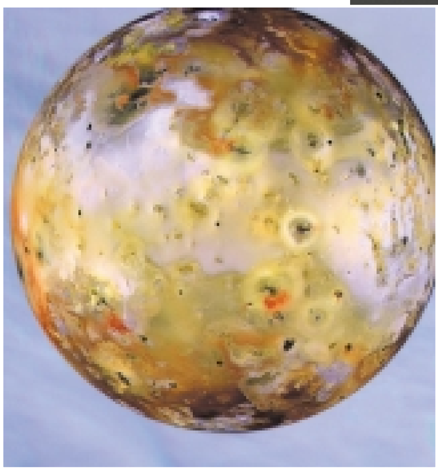


Figure 5.54 The moons of Jupiter that Galileo discovered nearly 400 years ago (Io, Europa, Ganymede, and Callisto) *Voyager* discovered to be terrestrial worlds unto themselves. One example is Io, the most volcanic world of all the planets and moons in the solar system.

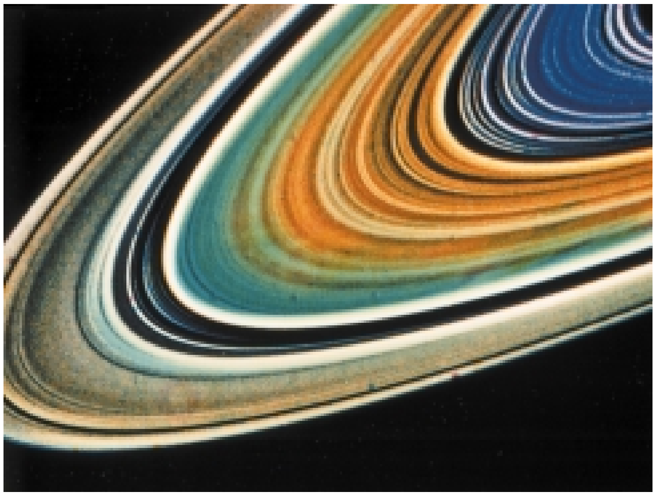


Figure 5.55 Saturn's rings as seen by *Voyager 2*.

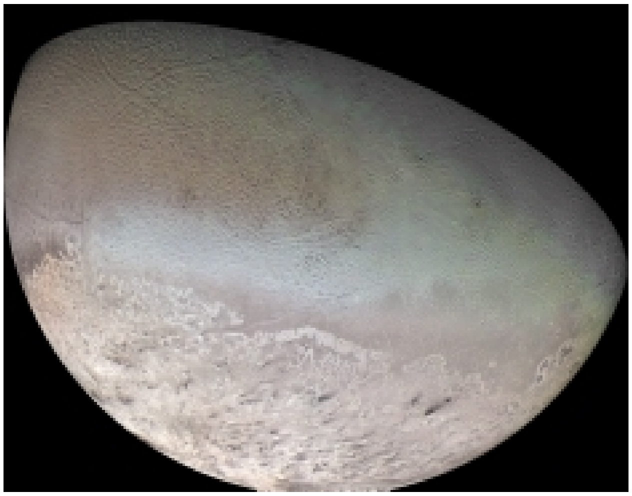


Figure 5.56 Ten new moons were discovered orbiting Neptune. *Voyager* mapped five of the largest ones. This photo is of the moon Triton. Its terrain looks like the skin of a cantaloupe where oceans of methane gases and nitrogen may rework the surface constantly.

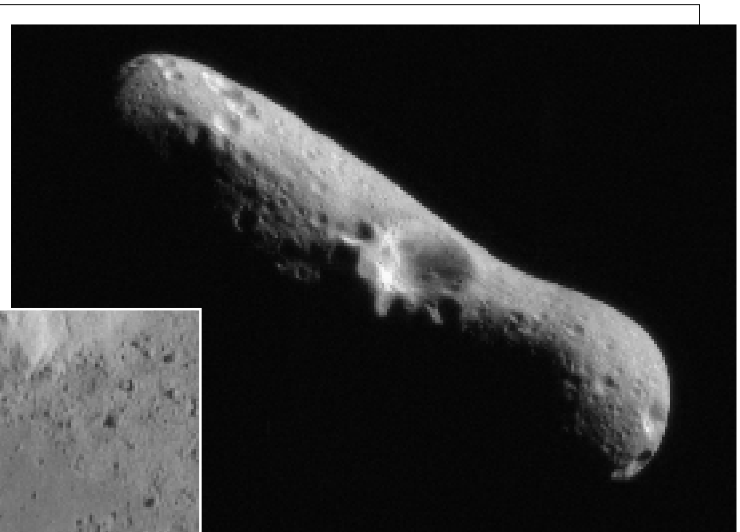
Voyager Today

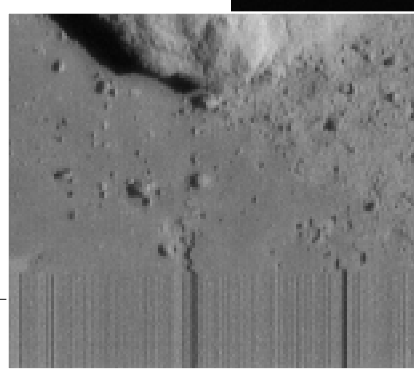
As of the year 2002, *Voyager 1* is about 12.5 billion km from Earth (9.8 billion km for *Voyager 2*). When scientists communicate with the *Voyagers*, they must allow for a time lag. Even though the radio signals travel at the speed of light, it takes several hours for a signal to complete a round trip from Earth to the spacecraft and back. By the start of the year 2002, the transmission time lag was over 23 h for *Voyager 1* and over 18 h for *Voyager 2*. This time lag increases by about 1 h per year.

DidYouKnow?

There are thousands of asteroids in the solar system. On February 12, 2001 NASA's NEAR (Near Earth Asteroid Rendezvous) satellite landed on Eros, a large asteroid. The large crater near the centre of Eros measures 6 km across.

The inset image was taken from a distance of 120 m. The image is of an area 6 m across and shows details on Eros's surface as small as a golf ball. The streaky lines at the bottom indicate loss of signal as the spacecraft touched down on the asteroid during transmission of this image.





TOPIC 7 Review

1. What is the solar wind?
2. How does the Sun release energy?
3. What technology enabled astronomers to map Venus's surface?
4. Name four surface features on Mars that are similar to features on Earth.
5. Why did the *Voyager* space probes need gravitational assists?
6. **Thinking Critically** Most of the worlds in the solar system that have solid surfaces show evidence of heavy cratering. Suggest a reason for this.