Key Terms
planet
solar system
retrograde motion
astronomical unit
orbital radius

# 7.4 Meet Your Solar System

The ancient Greeks noticed that five objects appeared to wander through the constellations. They were observing the five planets that you can see without binoculars or a telescope: Mercury, Venus, Mars, Jupiter, and Saturn. The ancient Greeks thought that these objects were special because they were not fixed against the background sky, like the stars appear to be. The word *planet* is from the Greek word for wanderer.

## The Planets

You have probably learned about the planets (shown in **Figure 7.23**) in earlier studies. There is now a more formal definition for the term *planet*. The International Astronomical Union defines a **planet** as an object that orbits one or more stars (and is not a star itself), is spherical, and does not share its orbit with another object. The planets, the Sun, and other smaller objects (see Section 7.5) make up the **solar system**. The Sun's gravitational pull keeps the objects in the solar system in orbit around the Sun.

**planet** an object that orbits one or more stars (and is not a star itself), is spherical, and does not share its orbit with another object

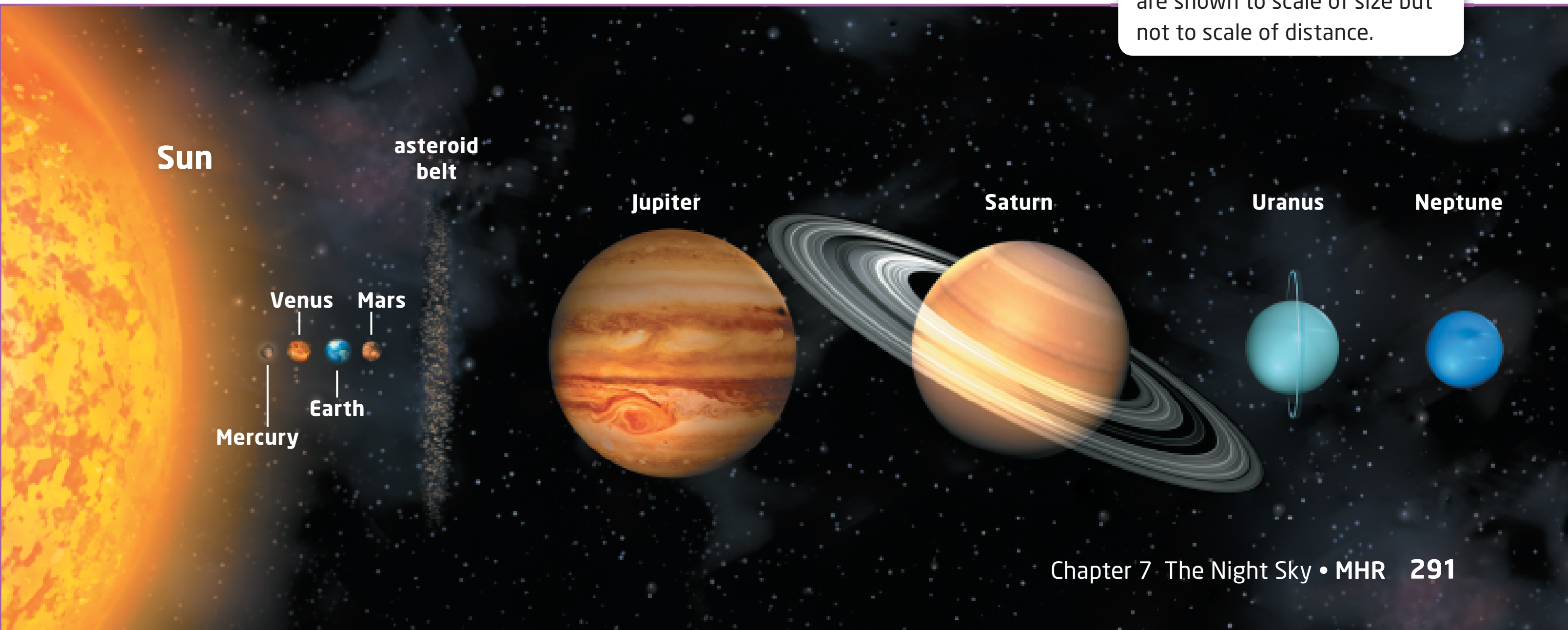
**solar system** a group of planets that circle one or more stars

## Models of the Solar System

The first model of the solar system stated that Earth was the centre of all planetary motion, with the planets and the Sun travelling in perfect circles around Earth. This model is called the *geocentric model* (*geo* means Earth). The geocentric model was based largely on the work of Ptolemy, a Greek astronomer in the second century C.E. The geocentric model remained the main model for almost 1500 years.

In the 1500s, Polish astronomer Nicolaus Copernicus (1473–1543) presented new observations and a new model for the solar system, called the heliocentric model. The *heliocentric model* (*helio* means Sun) places the Sun in the centre of the solar system and has the planets orbit the Sun in perfect circles. German astronomer Johannes Kepler (1571–1630) revised the heliocentric model by demonstrating that the orbits of the planets are ellipses.

**Figure 7.23** The eight planets are shown to scale of size but not to scale of distance.



### Classifications of the Planets

The planets Mercury, Venus, Earth, and Mars are called the *inner planets*. Sometimes they are called the *terrestrial* (Earth-like) planets. They are relatively small and have solid cores and rocky crusts. Farther away, large clumps of gas, ice, and dust formed what are called the *outer planets:* Jupiter, Saturn, Uranus, and Neptune. These planets are known for their large gaseous bands and cold temperatures. They are also called the *gas giants.*

#### Learning Check

1. Define the term *planet*.
2. List and describe two models of the solar system.
3. Compare and contrast the inner planets and the outer planets in a Venn diagram.
4. In a group, brainstorm what you think might happen if the Sun were not at the centre of the solar system.

## Planetary Motion

**retrograde motion** the movement of an object in the sky, usually a planet, from east to west, rather than in its normal motion from west to east

Venus and Mercury stay near the Sun. They can be seen only in the early evening or early morning. In comparison, on any given night, Mars, Jupiter, and Saturn move westward along with the fixed stars due to Earth's rotation. At certain times, however, these three planets "wander" against their starry background in a slow, looping motion that lasts several weeks.

This apparent change in direction is called **retrograde motion**. Retrograde motion is produced when Earth catches up with and passes an outer planet in its orbit. Earth is on an inside track and moves faster than the outer planets. Every time it catches up to an outer planet and moves between the outer planet and the Sun, the planet appears to make a looping motion, which is shown for Mars in **Figure 7.24**.

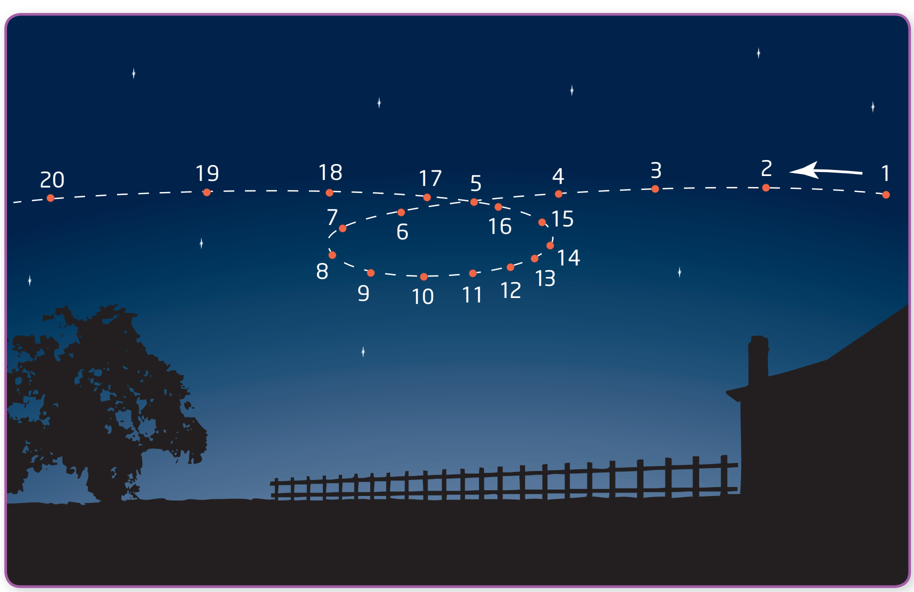



**Figure 7.24** This diagram shows the position of Mars compared with the background stars during a period of retrograde motion. Each point represents the planet's new position every 10 days over the retrograde period.

## Distances between the Planets

Large distances keep the planets well separated from each other. In fact, the planets lie so far apart that kilometres are not a meaningful way to measure the distances between them. Using kilometres would result in huge numbers that are difficult to work with. It would be like using millimetres to measure the longest hallway in your school or describing the cost of groceries in pennies. For this reason, astronomers created a unit for measuring distances in the solar system: the **astronomical unit (AU)**. The AU is equal to the average distance between Earth and the Sun—about 150 million kilometres. Therefore, by definition, Earth is 1 AU from the Sun. The average distance between the Sun and an object orbiting the Sun is called the **orbital radius**. The orbital radius is expressed in astronomical units.

The planets share many similar characteristics, but they also have many differences. The planet profiles that follow, in **Figure 7.25**, will give you a better idea of Earth's planetary neighbours. Note that Pluto is no longer considered a planet. You will learn why in Section 7.5.

**astronomical unit** the average distance between Earth and the Sun, about $150 \times 10^6$ km

**orbital radius** the average distance between the Sun and an object that is orbiting the Sun

**Suggested Investigation**

Data Analysis Investigation 7-C, Gravity on Other Planets, on page 310

# Activity 7-3

## Modelling the Solar System

The solar system is so vast and empty that it is impossible to draw the sizes of the Sun and planets and the distances between them to the same scale on a regular piece of paper. How can you model distances in the solar system? In this activity, you and your classmates will create a scale model of the solar system using the data in the table.

### Materials

- calculator
- construction paper
- coloured markers or pencils
- scissors
- long white paper tape
- glue or tape
- metre stick

**Diameters and Distances in the Solar System**

| Celestial Object | Diameter (km) | Distance from Sun (km) |
|---|---|---|
| Sun | 1 392 530 | |
| Mercury | 4 879 | 57 909 711 |
| Venus | 12 104 | 108 209 570 |
| Earth | 12 756 | 149 600 000 |
| Mars | 6 792 | 227 039 534 |
| Jupiter | 142 980 | 778 294 598 |
| Saturn | 120 540 | 1 423 872 155 |
| Uranus | 51 120 | 2 876 160 232 |
| Neptune | 49 530 | 4 515 865 992 |

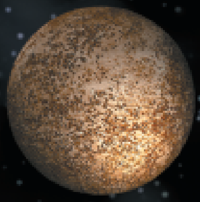
### Procedure

1. Work in groups of three or four. Calculate the scale diameter of the Sun and each planet using the scale 1 cm = 10 000 km. Calculate the scale distance of each planet from the Sun using the scale 20 cm = 149 600 000 km. Organize your data in a table, and give your table a title.
2. Cut out the Sun and each planet from construction paper according to the scaled sizes you calculated in step 1.
3. Lay the long white paper tape on the floor. Attach the Sun and each planet to the paper tape. Space them according to your distance scale. The Sun should start the tape.

### Questions

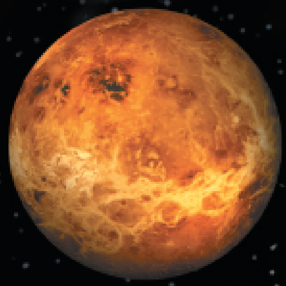
1. According to the scale you used for your model, how far (in metres) from the Sun is Neptune?
2. Using the data table on this page, calculate the distance of each planet from Earth. Then calculate how long it would take for an airplane to reach each planet from Earth. Use the speed 800 km/h. Add your data to the table you made in step 1.

## Mercury



Mercury, a rocky ball covered in craters, is only slightly larger than our Moon. At only 0.39 AU from the Sun, Mercury is the planet closest to the Sun (see **Table 7.1**). Because Mercury does not have an atmosphere, there are huge differences between day and night surface temperatures. The extreme heating and freezing that result from these temperature differences cause the rock to expand and contract, forming immense cracks in Mercury's surface.

## Venus

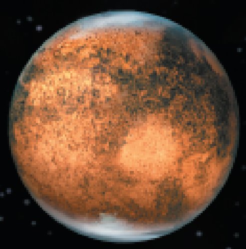


Venus is often called Earth's sister planet because its size and composition are similar to Earth's. The surface features of Venus are not visible from Earth because the planet is continuously shrouded in thick clouds. Sulfur mixes with moisture in Venus's atmosphere to rain down as sulfuric acid (acid rain). Venus's atmosphere also contains carbon dioxide and nitrogen. In 1990, the *Magellan* spacecraft began scanning the surface of Venus using radar. Data from *Magellan* revealed that large areas of Venus are very flat, while other areas have volcanoes, lava flows, and cracks called rifts. Venus is significantly hotter than Mercury because Venus's atmosphere traps the heat from the planet.

## Earth

Our little blue planet, third from the Sun, is home to the only life that scientists have discovered so far in the universe. Besides having a suitable atmosphere and temperatures for life to survive, Earth is the only place known to have water in three phases: liquid, solid, and gas. Water covers nearly three quarters of Earth's surface. Running water, atmospheric effects (such as wind), and plate tectonics (movements of Earth's crust) constantly shape the surface of Earth. Earth's atmosphere contains mainly nitrogen, oxygen, and water vapour.

## Mars



Mars is often called the red planet because the iron in its surface rocks gives it a rusty colour. Mars has a volcano that is three times higher than Mount Everest. Mount Everest is 8850 m high! There is also a canyon that is 8 km deep, which would stretch from Vancouver to Toronto, over 3300 km. The winds on Mars move at speeds of up to 900 km/h. On Earth, the strongest hurricanes have wind speeds of up to 250 km/h. Dust storms can cover the whole planet and last for weeks. Mars has two polar ice caps. Mars's very thin atmosphere is made mostly of carbon dioxide.

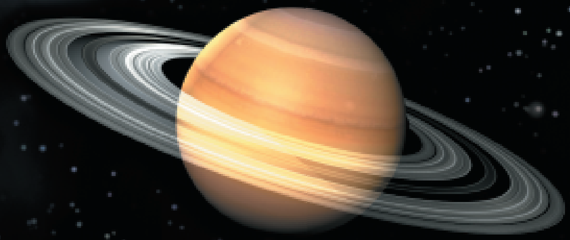
**Table 7.1 Properties of the Inner Planets**

| Planet | Orbital Radius (AU) | Radius (km) | Mass (relative to Earth) | Average Surface Temperature (°C) | Period of Rotation (relative to 1 Earth day) | Period of Revolution (relative to 1 Earth year) | Number of Moons |
|---|---|---|---|---|---|---|---|
| Mercury | 0.39 | 2440 | 0.05 | 179 | 58.90 | 0.24 | 0 |
| Venus | 0.72 | 6052 | 0.82 | 467 | 244.00 | 0.62 | 0 |
| Earth | 1.00 | 6378 | 1.00 | 17 | 1.00 | 1.00 | 1 |
| Mars | 1.52 | 3396 | 0.11 | –63 | 1.03 | 1.88 | 2 |

## Jupiter

The largest planet in the solar system is Jupiter. Its mass is 2.5 times greater than the total mass of all the other planets combined. See **Table 7.2**. Jupiter's Great Red Spot has been visible from Earth for more than 300 years. This spot, which is as large as three Earths, is a storm in the clouds of hydrogen and helium that form the planet's outer layers and atmosphere. Despite Jupiter's immense size, it has the shortest day of any of the planets, turning once on its axis every 10 hours. If Jupiter were 100 times more massive, it might have formed into a small, faint star. Jupiter has rings made of ice particles, but the rings are very thin.

## Saturn

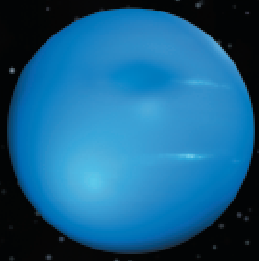


Saturn is easily identified by its elaborate system of rings. Saturn's rings are ice particles, which range in size from tiny specks to the size of a house. These rings are 250 000 km wide, but they can be as thin as 10 m. A sheet of paper the size of Toronto would have the same thickness-to-width ratio as Saturn's rings. The planet itself, including its atmosphere, is composed mainly of hydrogen and some helium.

## Uranus

Uranus is one of the gas giants. It is the fourth most massive planet in the solar system. Its composition is similar to the composition of Jupiter and Saturn, including a ring system composed of ice and dust. Uranus gets its distinctive blue-green colour from the methane gas in its atmosphere. (Methane absorbs red light and reflects blue-green light.) Its atmosphere also contains hydrogen and helium. Uranus has an unusual rotation–it is flipped on its side. As a result, it appears to be rolling through its orbit around the Sun.

## Neptune



Neptune is the outermost planet and the third most massive. Its composition and atmosphere are similar to those of Uranus, but Neptune is a darker blue colour. Neptune also has a very thin ring system made of ice particles.

**Figure 7.25**

**Table 7.2** **Properties of the Outer Planets**

| Planet | Orbital Radius (AU) | Radius (km) | Mass (relative to Earth) | Average Surface Temperature (°C) | Period of Rotation (relative to 1 Earth day) | Period of Revolution (relative to 1 Earth year) | Number of Moons |
|---|---|---|---|---|---|---|---|
| Jupiter | 5.20 | 71 490 | 317.8 | −150 | 0.41 | 11.86 | 61 |
| Saturn | 9.54 | 60 270 | 95.2 | −170 | 0.45 | 29.46 | 60 |
| Uranus | 19.18 | 25 560 | 14.5 | −215 | 0.72 | 84.01 | 27 |
| Neptune | 30.06 | 24 765 | 17.1 | −235 | 0.67 | 164.8 | 13 |

## Section 7.4 Review

### Section Summary

- Two models of the solar system are the geocentric model and the heliocentric model.
- The planets share many similar characteristics, but they also have many differences.
- The inner, or terrestrial, planets are rocky and small. The outer planets, or gas giants, are made of gases and are huge.
- The astronomical unit is defined as the average distance between Earth and the Sun.

### Review Questions

K/U **1.** Create a mnemonic device (memory aid) to help you remember the order of the planets from the Sun.

K/U **2.** According to the heliocentric model of the solar system, which celestial object is holding all the other celestial objects in orbit?

T/I **3.** If the Sun revolved around Earth, as in the geocentric model, what do you think the path of the Sun across the sky would look like?

K/U **4.** Explain why astronomers devised the astronomical unit.

T/I **5.** Compare the atmospheres of the planets by copying and completing the table for all the planets. What similarities and differences can you see among the planets?

**Planetary Atmospheres**

| Planet | Composition of Atmosphere |
|---|---|
| Mercury | |
| Venus | |
| Earth | |
| Mars | |
| | |

K/U **6.** Why does it seem that Uranus rolls on its side?

K/U **7.** Would a year on the planet Saturn be longer or shorter than a year on Earth? Explain your answer.

T/I **8.** Use **Tables 7.1** and **7.2** to compare the properties of the planets.

**a.** Create a bar graph to compare the radii (plural of radius) of the planets. Put the planets on the $x$-axis and the radius (in kilometres) on the $y$-axis. Why are the outer planets called the gas giants?

**b.** Create a bar graph to illustrate the distances of the planets from the Sun. Put the planets on the $x$-axis and the distances (in astronomical units) on the $y$-axis.