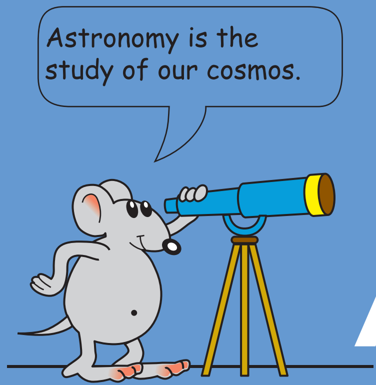
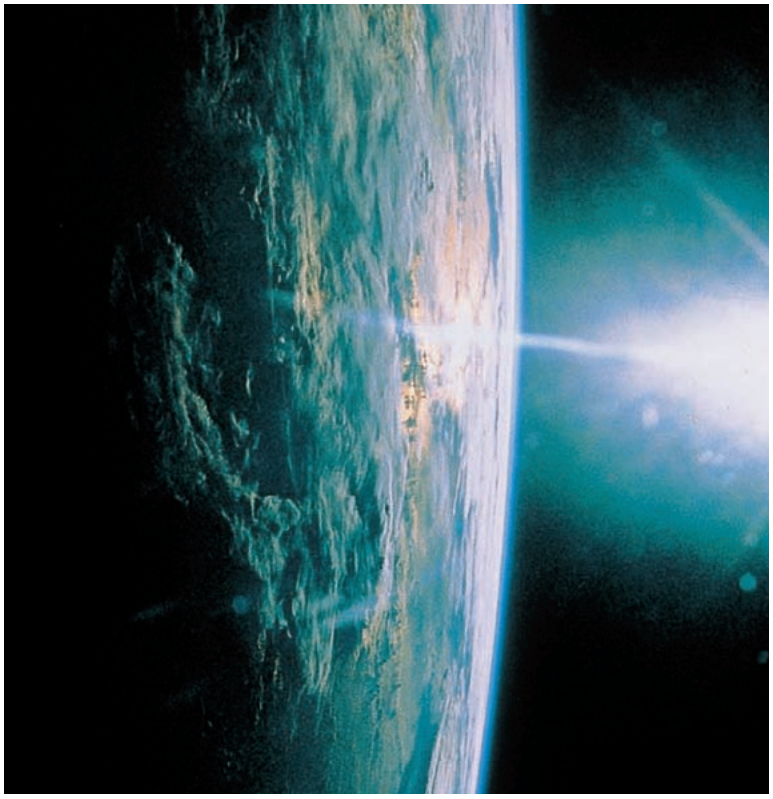


PART FIVE

ASTRONOMY

We began this book with the physics of the everyday world, then progressed to the submicroscopic world of chemistry. Then we explored Earth science, big by comparison. And now we conclude our explorations by studying the arena of the very big—the solar system, stars, galaxies, and the universe itself. We'll learn, for example, how the Moon, seen here in stages of an eclipse, becomes red due to sunsets all over the world. To astronomy!



32

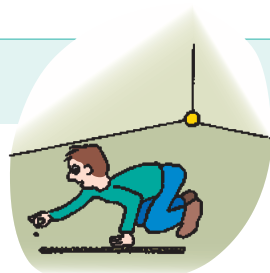
THE SOLAR SYSTEM

THE MAIN IDEA

Many different types of objects orbit our Sun including planets, asteroids, comets, and dwarf planets.

Five billion years ago, there was no Sun. Instead, the region of the galaxy that would become our solar system was a gently swirling, diffuse cloud of gas and dust. How then did this cloud evolve into our present solar system? How are the planets similar, and how are they different? How did our Moon form and how does it go through phases? Why do we see only one side of the Moon? What are meteors, asteroids, and comets? How frequently do they collide with our planet, and why does a comet's tail always point away from the Sun?

Explore!



How Large Is the Solar System?

Use a tennis ball to represent the Sun and place it in a corner of the room. To scale, the four inner planets would each be about as large as a grain of salt. Place a single grain of salt representing Mercury about 3 meters away from the tennis ball. For Venus, place a grain about 5 meters away. The grain representing Earth should be placed 7 meters away and Mars about 11 meters away.

Analyze and Conclude

1. **Observing** Is the solar system made mostly of planets or of empty space?
2. **Predicting** If the Sun were the size of a tennis ball, the largest planet in our solar system, which is Jupiter, would be about as large as a green pea. How far should this pea be placed away from the tennis ball? (*Hint:* Jupiter is 5 times farther away from the Sun than Earth.)
3. **Making Generalizations** Our most distant planet, Neptune, is about 30 times farther from the Sun than Earth. If the Sun were the size of a tennis ball, would all the planets fit within your school grounds? How about the outermost reaches of our solar system, which are about 50,000 times as far from the Sun?

32.1 The Solar System Is Mostly Empty Space

Our solar system is a collection of objects gravitationally bound to the Sun. Along with the Sun itself, the solar system contains eight **planets.** The planets all lie roughly in the same plane. This plane, called the **ecliptic,** is defined as the plane of Earth's orbit. Within the solar system are also numerous moons (objects orbiting planets), asteroids (small, rocky bodies), comets (small, icy bodies), and a collection of miniature planets known as dwarf planets, or *plutoids*, that orbit on the outer edges of the solar system. The most well-known plutoid is Pluto, which was downgraded from planet status in 2006. The planets and all these other objects are quite small compared to the Sun.

The vast distances between the Sun and the objects orbiting it can be grasped by imagining the Sun reduced to the size of a tennis ball. The four innermost planets would each be about as large as a grain of salt, all within 11 meters of this tennis-ball-sized Sun.

These first four **inner planets**—Mercury, Venus, Earth, and Mars—are small, solid rocky planets. The **outer planets** are larger gaseous planets located much farther away. The first outer planet is Jupiter, which on the scale mentioned would be the size of a pea more than 25 m away. The second outer planet, Saturn, famous for its extensive ring system, would be the size of a smaller pea more than 65 m away. Planets Uranus and Neptune would both be about the size of grains of rice located 135 and 210 m away, respectively. We see that solar system objects are mere specks in the vastness of the space about the Sun.

Because of these vast interplanetary distances, astronomers use the *astronomical unit* to measure them. One **astronomical unit** (AU) is the distance from Earth to the Sun, which is about 150,000,000 km. Table 32.1 gives the distances of planets from the Sun in AU. The data in Table 32.1 also show the division of the planets into two groups with similar properties. The inner planets—Mercury, Venus, Earth, and Mars—are solid and relatively small and dense. They are called the

The stars appear fixed in their patterns in the sky, but the planets wander from night to night. The term *planet* is derived from Greek for "wandering star."

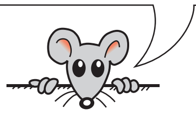


FIGURE 32.1 This illustration shows the order and relative sizes of planets. Moving away from the Sun, we have in order: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The planets range greatly in size, but the Sun dwarfs them all—containing more than 99% of the mass in the solar system. (*Note:* distances are not to scale in this illustration.)

TABLE 32.1 Planetary Data

	Mean Distance from Sun (Earth distances, AU)	Orbital Period (years)	Diameter		Mass		Density	Inclination
			(km)	(Earth = 1)	(km)	(Earth = 1)	(g/cm^3)	to Ecliptic
Sun			1,392,000	109.1	1.99×10^{30}	3.3×10^{5}	1.41	
Terrestrial								
Mercury	0.39	0.24	4,880	0.38	3.3×10^{23}	0.06	5.4	7.0°
Venus	0.72	0.62	12,100	0.95	4.9×10^{24}	0.81	5.2	3.4°
Earth	1.00	1.00	12,760	1.00	6.0×10^{24}	1.00	5.5	0.0°
Mars	1.52	1.88	6,800	0.53	6.4×10^{23}	0.11	3.9	1.9°
Jovian								
Jupiter	5.20	11.86	142,800	11.19	1.90×10^{27}	317.73	1.3	1.3°
Saturn	9.54	29.46	120,700	9.44	5.7×10^{26}	95.15	0.7	2.5°
Uranus	19.18	84.0	50,800	3.98	8.7×10^{25}	14.65	1.3	0.8°
Neptune	30.06	164.79	49,600	3.81	1.0×10^{26}	17.23	1.7	1.8°
Plutoid								
Pluto	39.44	247.70	2,300	0.18	1.3×10^{22}	0.002	1.9	17°
Eris	67.67	557	2,400	0.19	1.6×10^{22}	0.002	1.9	44°

terrestrial planets. The outer planets are large, have many rings and satellites, and are composed primarily of hydrogen and helium gas. These are called the *jovian* (Latin for Jupiter) planets because their large sizes and gaseous compositions resemble Jupiter.

READING CHECK

What is the ecliptic?

32.2 Solar Systems Form from Nebula

Any theory of solar system formation must be able to explain (1) *the orderly motions among the bodies of our solar system* and (2) *the division of planets into two main types*—terrestrial *and* jovian. The modern scientific theory that meets these requirements is called the *nebular theory*. The **nebular theory** proposes that a solar system forms from a cloud of gas and dust. The word *nebula* is Latin for "cloud." With telescopes, we can see many distant nebula, all at different stages of solar system formation. An example is shown in Figure 32.2.

FIGURE 32.2 ▶
This photograph, provided by the Hubble Telescope, shows the Orion Nebula. The Orion Nebula, like the nebula from which our solar system formed, is an interstellar cloud of gas and dust and the birthplace of stars.