19. What is the meaning of the letters R I V U X G that appear under some of the figures in this chapter? Why in each case is one of the letters highlighted? (Hint: See the section “How to Use This Textbook” that precedes Chapter 1.)

20. The diameter of the Sun is 1.4 x 10^11 cm, and the distance to the nearest star, Proxima Centauri, is 4.2 ly. Suppose you want to build an exact scale model of the Sun and Proxima Centauri, and you are using a ball 30 cm in diameter to represent the Sun. In your scale model, how far away would Proxima Centauri be from the Sun? Give your answer in kilometers, using powers-of-ten notation.

21. How many Suns would it take, laid side by side, to reach the nearest star? Use powers-of-ten notation. (Hint: See the preceding question.)

22. A hydrogen atom has a radius of about 5 x 10^-9 cm. The radius of the observable universe is about 14 billion light-years. How many times larger than a hydrogen atom is the observable universe? Use powers-of-ten notation.

23. The Sun’s mass is 1.99 x 10^30 kg, three-quarters of which is hydrogen. The mass of a hydrogen atom is 1.67 x 10^-27 kg. How many hydrogen atoms does the Sun contain? Use powers-of-ten notation.

24. The average distance from the Earth to the Sun is 1.496 x 10^8 km. Express this distance (a) in light-years and (b) in parsecs. Use powers-of-ten notation. (c) Are light-years or parsecs useful units for describing distances of this size? Explain.

25. The speed of light is 3.00 x 10^8 m/s. How long does it take light to travel from the Sun to Earth? Give your answer in seconds, using powers-of-ten notation. (Hint: See the preceding question.)

26. When the Voyager 2 spacecraft sent back pictures of Neptune during its flyby of that planet in 1989, the spacecraft’s radio signals traveled for 4 hours at the speed of light to reach Earth. How far away was the spacecraft? Give your answer in kilometers, using powers-of-ten notation. (Hint: See the preceding question.)

27. The star Procyon is 3.50 pc from Earth. (a) What is the distance to Procyon in kilometers? Use powers-of-ten notation. (b) How long does it take for light emanating from Procyon to reach Earth? Give your answer in years. (Hint: You do not need to know the value of the speed of light.)

28. The age of the universe is about 14 billion years. What is this age in seconds? Use powers-of-ten notation.

29. Explain where the number 206,265 in the small-angle formula comes from.

30. At what distance would a person have to hold a European 2-euro coin (which has a diameter of about 2.6 cm) in order for the coin to subtend an angle of (a) 1°? (b) 1 arcmin? (c) 1 arcsec? Give your answers in meters.

31. A person with good vision can see details that subtend an angle of as small as 1 arcminute. If two dark lines on an eye chart are 2 millimeters apart, how far can such a person be from the chart and still be able to tell that there are two distinct lines? Give your answer in meters.

32. The average distance to the Moon is 384,000 km, and the Moon subtends an angle of 1/6°. Use this information to calculate the diameter of the Moon in kilometers.

33. Suppose your telescope can give you a clear view of objects and features that subtend angles of at least 2 arcsec. What is the diameter of the smallest crater you can see on the Moon? (Hint: See the preceding question.)

34. On January 11, 2003, the planet Venus was a distance of 0.719 AU from Earth. The diameter of Venus is 12,104 km. What was the angular size of Venus as seen from Earth on January 11, 2003? Give your answer in arcminutes.

Discussion Questions

35. Scientists assume that “reality is rational.” Discuss what this means and the thinking behind it.

36. All scientific knowledge is inherently provisional. Discuss whether this is a weakness or a strength of the scientific method.

37. How do astronomical observations differ from those of other sciences?

Web/CD-ROM Questions

38. Use the links given in the Universe Web site, Chapter 1, to learn about the Orion Nebula (Figure 1-5). Can the nebula be seen with the naked eye? Does the nebula stand alone, or is it part of a larger cloud of interstellar material? What has been learned by examining the Orion Nebula with telescopes sensitive to infrared light?

39. Use the links given in the Universe Web site, Chapter 1, to learn more about the Crab Nebula (Figure 1-6). When did observers on Earth see the supernova that created this nebula? Does the nebula emit any radiation other than visible light? What kind of object is at the center of the nebula?

40. Search the World Wide Web to learn more about Topex/Poseidon (see Figure 1-13) and other space missions that study the Earth. What are an “El Niño” and a “La Niña”? How can they be detected from space? How can the speed of winds over the oceans be measured by an orbiting satellite?

41. Access the AIMM (Active Integrated Media Module) called “Small-Angle Toolbox” in Chapter 1 of the Universe CD-ROM or Web site. Use this to determine the diameters in kilometers of the Sun, Saturn, and Pluto given the following distances and angular sizes:

<table>
<thead>
<tr>
<th>Object</th>
<th>Distance (km)</th>
<th>Angular size (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>1.5 x 10^8</td>
<td>1800</td>
</tr>
<tr>
<td>Saturn</td>
<td>1.5 x 10^9</td>
<td>16.5</td>
</tr>
<tr>
<td>Pluto</td>
<td>6.3 x 10^9</td>
<td>0.06</td>
</tr>
</tbody>
</table>
42. On a dark, clear, moonless night, can you see the Milky Way from where you live? If so, briefly describe its appearance. If not, what seems to be interfering with your ability to see the Milky Way?

43. Look up at the sky on a clear, cloud-free night. Is the Moon in the sky? If so, does it interfere with your ability to see the fainter stars? Why do you suppose astronomers prefer to schedule their observations on nights when the Moon is not in the sky?

44. Look up at the sky on a clear, cloud-free night and note the positions of a few prominent stars relative to such reference markers as rooftops, telephone poles, and treetops. Also note the location from where you make your observations. A few hours later, return to that location and again note the positions of the same bright stars that you observed earlier. How have their positions changed? From these changes, can you deduce the general direction in which the stars appear to be moving?

45. Use the CD-ROM that accompanies this book to install the Starry Night Backyard™ planetarium software on your computer. Use Starry Night Backyard™ to determine when the Moon is visible today during the day and when it is visible tonight. Determine which, if any, of the following planets are visible tonight: Mercury, Venus, Mars, Jupiter, and Saturn. Hints: (1) Feel free to experiment with Starry Night Backyard™. You can always return to your starting screen by selecting Go Home from the View menu. To see the sky from your actual location on Earth, select Viewing Location... in the View menu, then scroll through the list of locations to find your city or town. (2) To change your viewing direction, move the mouse until the cursor changes into a little hand. Then, hold down the mouse button (on a Windows computer, the left button) as you move the mouse and you will move the sky. (3) Use the Control Panel at the top of the main window to change the time and date that is displayed as well as how rapidly time appears to change. (4) Use the Find... command in the Edit menu to locate specific planets or stars by name. (5) To learn about any object in the sky, point the cursor at the object and double-click the mouse.

You can find even more information about the program in the Starry Night Backyard™ manual (in Starry Night Backyard™, select User's Guide or Manual in the Help menu).

46. Use the CD-ROM that accompanies this book to install the Deep Space Explorer™ software on your computer. Then use Deep Space Explorer™ to investigate the Milky Way Galaxy. When the program starts up, you will see the Milky Way as it would appear from a great distance. A box near the bottom of the screen shows your distance from the Sun, which lies within the Milky Way. (Moving the cursor over any object on the screen shows you the name of the object, the object's distance from your position in space, and the object's apparent magnitude—a measure of how bright it appears from your position.) (a) You can rotate the Milky Way (as though you were viewing it from different angles) by putting the mouse cursor over the image, holding down the mouse button, and moving the mouse. (On a two-button mouse, hold down the left mouse button.) How would you describe the shape of the Milky Way? (b) You can zoom in and zoom out using the buttons at the upper left of the window (an upward-pointing triangle and a downward-pointing triangle). Zoom in until you can see the planets in their orbits around the Sun, then zoom back out until you can again see the entire Milky Way Galaxy. Are the Sun and planets located at the center of the Milky Way? How would you describe their location?

Collaborative Exercises

47. A scientific theory is fundamentally different than the everyday use of the word “theory.” List and describe any three scientific theories of your choice and creatively imagine an additional three hypothetical theories that are not scientific. Briefly describe what is scientific and what is nonscientific about each of these theories.

48. Angular measure describes how far apart two objects appear to an observer. From where you are currently sitting, estimate the angular distance between the floor and the ceiling at the front of the room you are sitting in, the angular distance between the two people sitting closest to you, and the angular size of a clock or an exit sign on the wall. Draw sketches to illustrate each answer and describe how each of your answers would change if you were standing in the very center of the room.

49. Astronomers use powers of ten to describe the distances to objects. List an object or place that is located at very roughly each of the following distances from you: $10^{-2}$ m, $10^0$ m, $10^1$ m, $10^3$ m, $10^7$ m, $10^{10}$ m, and $10^{20}$ m.