Cosmic Perspective 10th edition Bennett Test Bank

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Chapter-by-Chapter Guide

Part I: Developing Perspective

The remainder of this Instructor Guide goes through the book chapter by chapter. Each chapter is organized as follows:

- A brief introduction with general comments about the chapter.
- Teaching Notes: Organized section by section for the chapter, these are essentially miscellaneous notes that may be of use to you when teaching your course.
- Answers/Discussion Points for Think About It and See It for Yourself Questions.
- Solutions to End-of-Chapter Problems.

Chapter 1. A Modern View of the Universe

The purpose of this first chapter is to provide students with the contextual framework they need to learn the rest of the course material effectively: a general overview of the scale of the universe (Section 1.1), the history of the universe and the scale of time (Section 1.2), and an overview of motion in the universe (Section 1.3). We often tell students that, after completing this first chapter, they have essentially learned all the major ideas of astronomy, and the rest of their course will be building the detailed scientific case for these general ideas.

As always, when you prepare to teach this chapter, be sure that you are familiar with the online quizzes, interactive figures and tutorials, assignable homework, and other resources available on the Mastering Astronomy Web site.

Key Changes for the 10th Edition: For those who have used earlier editions of our textbook, please note the following significant changes in this chapter:

- New Chapter Opening image: Using the first deep field released from JWS T in place of the Hubble Extreme Deep Field. This should provide a great opportunity to discuss recent JWST discoveries that came after this edition went to press in early fall 2022.
- We have dropped the former short Section 1.4 (“The Human Adventure of Astronomy”), based on comments that it was redundant with what we’ve already stated in this chapter and discuss further in later chapters.
- Clarifications on number of galaxies in the Local Group and universe to reflect recent discoveries.

Note on Mathematics: The MasteringAstronomy Web site has a set of Math Review videos and brief, assignable tutorials that we created to cover basic topics like fractions, scientific notation, and unit analysis. Those instructors who include some mathematical work (such as covering the Mathematical Insight boxes or assigning end-of-chapter quantitative exercises) may wish to assign these videos and tutorials along with the first couple of chapters of the text.

Teaching Notes (by Section)

Section 1.1 The Scale of the Universe

This section provides a brief overview of our place in the universe, including the hierarchical structure of the universe (our cosmic address) and the scale of the universe.

- Our emphasis on scale may seem unusual to those who have not taught from our book previously. However, we believe it is an extraordinarily important topic that generally is underappreciated by students. Most students enter our course without any realistic view of the true scale of the universe, and without the context of scale, they are likely to misinterpret much of the rest of the content and detail in an astronomy course.
- Note that the section begins with a brief discussion of the JWST deep field image in the Chapter Opening photo, which helps set the context for an overview of our place in the universe.
- Note the box on “Basic Astronomical Definitions”: Although some of the terms in this box are not discussed immediately, having them here in the beginning of the book should be helpful to students. All these terms also appear in the Glossary, but they are so basic and important that we want to emphasize them here in Chapter 1.
- This section introduces astronomical distance measurements in AU and light-years. A couple of notes on our choices and definitions:
    - There are several different ways to define an average distance between Earth and the Sun (e.g., averaged over phase, over time, etc.). In defining an astronomical unit (AU) as the *average* distance between Earth and the Sun, we are using the term *average* to mean $(\text{perihelion} + \text{aphelion})/2$, which is equivalent to the semimajor axis. This has advantages when it comes to discussing Kepler’s third law, as it is much easier for students to think of *a* in the equation $p^2 = a^3$ as *average* than as *semimajor axis*.
    - Note that we’ve chosen to use *light-years* rather than *parsecs* as our primary unit for stellar and galactic distances for three reasons: (1) We have found that light-years are more intuitive than parsecs to most

students because light-years require only an understanding of light travel times, and not of the more complex trigonometry of parallax. (2) Lookback time is one of the most important concepts in astronomy, and the use of light-years makes it far easier to think about lookback times (e.g., when a student hears that a star is 100 light-years away, he/she can immediately recognize that we're seeing light that left the star 100 years ago). (3) Fortuitously, 1 light-year happens to be very close to 10^{13} kilometers $(9.46 \times 10^{12}\text{ kilometers}),$ making approximate unit conversions very easy, which by extension helps students remember that light-years are a unit of distance, not of time.

- Note that in discussing distances to very distant galaxies, we give distances in terms of lookback times. For example, when we say "7 billion light-years," we mean a lookback time of 7 billion years. With this definition, the radius of the observable universe is about 14 billion light-years, corresponding to the age of the universe. Note that some media reports instead quote distances as they would be today with the ongoing expansion, for example, saying that the universe is 40+ billion light-years in radius. As a result, some students may be confused about which is the "real" radius of the observable universe. To alleviate this confusion, it is worth pointing out (and we discuss this further in Chapter 20) that
  - "Distance" is ambiguous in an expanding universe; e.g., do you mean an object's distance at the time the light left, or now, or some time in between? The choice is arbitrary, with no particular choice (such as "now") being any better than any other (such as "at the time the light left").
  - In contrast, "lookback time" is unambiguous—it is the actual amount of time that the light has been traveling to reach us.
  - Given the above, we feel that lookback time is a much better way to describe distances.
- For our discussion of scale, we begin by making use of the 1-to-10-billion scale of the Voyage scale model solar system in Washington, D.C., a project that was proposed by *The Cosmic Perspective* author Jeff Bennett. Voyage replicas are being developed for other science centers and universities; if you are interested in learning more about how to get a Voyage replica in your town, please contact Jeff by e-mail (hjeff@bigkidscience.com).
- With regard to the count to 100 billion, it can be fun in lecture to describe what happens when you ask children how long it would take. Young children inevitably say they can count much faster than one per second. But what happens when they get to, say, "twenty-four billion, six hundred ninety-seven million, five hundred sixty-two thousand, nine hundred

seventy-seven . . .”? How fast can they count now? And can they remember what comes next?

- Regarding our statement that there are “more than 100 billion large galaxies in the observable universe.” You have probably heard news reports suggesting that the number of galaxies is more than 1 trillion. However, these reports are including galaxy counts in different epochs (based on distant observations), and there were more galaxies in the past than there are today, due to mergers. In addition, the number of galaxies depends on the cutoff size used. That is why we qualify our statement as “large” galaxies, meaning comparable in size to the Milky Way, for which 100 to 200 billion remains a reasonable estimate.
- Regarding our claim that the number of stars in the observable universe is roughly the same as the number of grains of sand on all the beaches on Earth, here are the assumptions we’ve made:
    - We are using 10^{22} as the number of stars in the universe. Assuming that grains of sand typically have a volume of $1\ \text{mm}^3$ (correct within a factor of 2 or 3), 10^{22} grains of sand would occupy a volume of 10^{22}mm^3 or 10^{13}m^3.
    - We estimate the depth of sand on a typical beach to be about 2–5 meters (based on beaches we’ve seen eroded by storms) and estimate the width of a typical beach at 20–50 meters; thus, the cross-sectional area of a typical beach is roughly $100\ \text{m}^2$.
    - With this $100\ \text{m}^2$ cross-sectional area, it would take a length of 10^{11} meters, or 10^8 kilometers, to make a volume of 10^{13}m^3. This is almost certainly greater than the linear extent of sandy beaches on Earth.

Section 1.2 The History of the Universe

This section provides a brief overview of our place in time, including an overview of the history of the universe (our cosmic origins) and the scale of time.

- As in the first section, we include a major emphasis on scale—in this case, the scale of time. Be sure to point out the backside of the foldout in the front of the book, which is called “You Are Here in Time” and is in some sense a summary of this section.
- We give the age of the universe as “about 14 billion years”; we feel this rounding to two significant digits makes it easier for students to understand, given that the current best estimate age (from the Planck mission) is 13.82 billion years, with a 1 sigma error bar of about 0.1 billion years.

- The idea of a "cosmic calendar" was popularized by Carl Sagan. Now that we've calibrated the cosmic calendar to a cosmic age of 14 billion years, note that 1 average month = 1.17 billion years.

Section 1.3 Spaceship Earth

This section completes our overview of the "big picture" of the universe by focusing on motion in the context of the motions of Earth in space, using R. Buckminster Fuller's idea of *Spaceship Earth*.

- Note that the summary figure for this section comes at its end, in Figure 1.18.
- We use the term *tilt* rather than *obliquity* as part of our continuing effort to limit the use of jargon.
- We note that universal expansion generally is not discussed until very late in other books. However, it's not difficult to understand through the raisin cake analogy; most students have heard about it before (although few know what it means), and it's one of the most important aspects of the universe as we know it today. Given all that, why wait to introduce it?
    - *Note:* Students may have seen a demonstration of expansion using a balloon and a marker. This illustration, however, is flawed in that the marks (usually described as the galaxies) are also becoming larger. That is why, when we introduce the balloon analogy later (in Chapter 20), we use buttons that do not change size as the balloon expands. For now, you can help students overcome this misconception by pointing out that the raisins in the raisin cake do not become larger as the raisin cake expands, much like the galaxies do not get larger during expansion.
- Similarly, we briefly introduce the ideas of dark matter and dark energy, since students have almost undoubtedly heard of them in the media.
- With regard to our solar system's distance from the center of the galaxy, the literature offers values over a fairly wide range; for example:
    - $27{,}100 \pm 500$ lt-yr (Gillessen et al. 2017, from stellar orbits around central BH)
    - $27{,}000 \pm 1300$ lt-yr (Pietrowicz et al. 2015, from RR Lyrae)
    - $27{,}200 \pm 500$ lt-yr (Reid et al. 2014, VLBI of water masers near GC)

Based on these recent results, the value of 27,000 light-years that we use in the text is consistent with all three ranges.

Answers/Discussion Points for Think About It/See It for Yourself Questions

The Think About It and See It for Yourself questions are not numbered in the book, so we list them in the order in which they appear, keyed by section number.

Section 1.1

- (p. 2) This question is, of course, very subjective, but can make for a lively in-class debate.
- (p. 4, SIFY) The main goal of this activity is for students to go out and look for the Andromeda Galaxy and contemplate seeing light that has been traveling through space for 2.5 million years. If people in the Andromeda Galaxy were looking at the Milky Way, they would see a spiral galaxy looking much like their galaxy looks to us. They would see our galaxy as it was about 2.5 million years ago (due to light travel time) and thus could not know that our civilization exists here today.
- (p. 10) This question can be a great topic of debate. We've found that most students tend to think it is inconceivable that we could be the only intelligent beings. However, some religious students will assume we are alone on grounds of their faith. In both cases, the question can generate discussion about how science has no firm stance without evidence. For example, we don't assume there are others because we have no evidence that there are, and we don't assume we are alone for the same reason.
- (p. 10) This is another very subjective question, but it should get students thinking about the size of Earth in the cosmos. At the least, most students are very surprised at how small our planet seems in relation to the solar system. For most students, its small size makes Earth seem a little more fragile, and often makes them think more about how we can best take care of our planet.

Section 1.2

- (p. 14) This is another very subjective question, similar to the one at the end of Section 1.1 but focused on our place in time rather than in space.

Section 1.3

- (p. 16) As we authors understand it, the only real reason that globes are oriented with north on top is because most of the early globe makers lived in the Northern Hemisphere. In any case, it is certainly equally correct to have the globe oriented in any other way.

- (p. 17) This question is easy to discuss if you refer to the 1-to-10-billion scale model developed earlier. On this scale, entire star systems are typically only a few hundred meters in diameter (including all their planets), while they are separated from other systems by thousands of kilometers (at least in our vicinity of the galaxy).
- (p. 18) This question just checks student understanding of the raisin cake figure. For a raisin that starts out at 10 cm, after 1 hour it is 30 cm away, which means it appears to be moving away from the Local Raisin at a speed of 20 cm/hr.

Solutions to End-of-Chapter Problems (Chapter 1)

Visual Skills Check

1. b
2. c
3. c
4. No. The nearest stars would not fit on Earth using this scale. The total distance to the nearest star would wrap around the Earth about 2.5 times!

Quick Quiz

1. a
2. b
3. c
4. b
5. a
6. b
7. c
8. b
9. a
10. a

Review Questions

11. The largest scale is the universe itself, which is the sum total of all matter and energy. The largest known organized structures are superclusters of galaxies, then clusters and groups of galaxies, and then the roughly 100 billion individual galaxies, most of which are many thousands of light-years across. Each galaxy contains billions of stars, and many (or most) stars may be orbited by planets.

12. Astronomical unit: the average distance between Earth and Sun, which is about 1.496×10^8 kilometers. Light-year: the distance that light travels in 1 year, which is about 9.46 trillion kilometers.

13. Because light travels at a fixed speed, it takes time for it to go between two points in space. Although light travels very quickly, the distances in the universe are so large that the time for light to travel between stars is years or longer. The farther away we look, the longer it takes light to have traveled to us from the objects. So the light we see from more distant objects started its journey longer ago. This means that we see, when we look at more distant objects, how they looked longer ago in time. So looking farther away means looking further back in time.

14. The observable universe is the portion of the entire universe that we can, in principle, see; it is about 14 billion light-years in radius, because light from more than 14 billion light-years away could not yet have reached us during the 14 billion years since the Big Bang. Scientists currently think that the entire universe is larger than the observable universe.

15. Solar system: On the 1-to-10-billion scale, the Sun is about the size of a grapefruit and the planets are the sizes of marbles or smaller. The distances between the planets are a few meters (for the inner solar system) to many tens of meters (in the outer solar system).

    Distances to nearby stars: On the same scale, the nearest stars are thousands of kilometers away.

    The Milky Way Galaxy: One way to understand the size of our galaxy is to note that if the Milky Way were the size of a football field, then the distance to the nearest star would be about 4 millimeters. The number of stars in the galaxy is more than 100 billion, so many that it would take thousands of years to count them aloud.

    The observable universe: One way to get a sense of the size of the observable universe is to note that the number of stars in it is comparable to the number of grains of sand on all of the beaches on Earth.

16. When we say that the universe is expanding, we mean that the average distance between galaxies is increasing with time. If the universe is expanding, then if we imagine running time backward, we'd see the universe shrinking. This suggests that the universe may have been very tiny and dense at some point in the distant past and has been expanding ever since.

This beginning is what we call the Big Bang. Based on observations of the expansion rate, the Big Bang must have occurred about 14 billion years ago.

17. We are "star stuff" because most of the atoms in our bodies (all the elements except for hydrogen, since our bodies generally do not contain helium) were made by stars that died long ago. These elements were released into space when the stars died, expelling their materials. The material was then incorporated into new generations of stars. This is how our solar system obtained those elements, some of which then formed the Earth, and ultimately, us.

18. There are numerous ways to describe how humanity fits into cosmic time, but here is one straight from the cosmic calendar: If the entire history of the universe were compressed into a single year, modern humans would have evolved only 2 minutes ago and the pyramids would have been built only 11 seconds ago.

19. Earth rotates once each day on its axis and orbits the Sun once each year. The ecliptic plane is the plane defined by Earth's orbit around the Sun. Most of the other planets orbit near this same plane. Axis tilt is the amount that a planet's axis of rotation is tipped relative to a line *perpendicular* to the ecliptic plane.

20. The Milky Way Galaxy is a spiral galaxy, which means that it is disk-shaped with a large bulge in the center. The galactic disk includes a few large spiral arms. Our solar system is located about 27,000 light-years from the center of the galaxy. Our solar system orbits about the galactic center in a nearly circular orbit, making one trip around every 230 million years.

21. The idea that most of our galaxy's mass is dark matter—meaning matter that does not emit light and is therefore invisible to our telescopes—comes from observing the speeds at which objects at different distances orbit the galactic center. These speeds depend on the strength of gravity, and indicate that there must be much more mass present than we can see. Dark energy is the name given to whatever is causing the expansion of the universe to accelerate with time. Dark matter and dark energy are mysterious because we don't know exactly what they are, and they are important because the make up the majority of the total energy content of the universe.

22. Edwin Hubble discovered that most galaxies are moving away from our galaxy, and more distant galaxies are moving away at higher speeds. While at first this might seem to suggest that we are at the center of the universe, a little more reflection indicates that this is not the case. If we imagine a raisin cake rising, we can see that every raisin will move away from every other raisin. So each raisin will see all of the others moving away from it, with more distant ones moving away faster—just as Hubble observed galaxies to be moving. Thus, just as the raisin observations can be

explained by the fact that the raisin cake is expanding, Hubble's galaxy observations tell us that our universe is expanding.

Think Critically

23. *Our solar system is bigger than* some *galaxies*. This statement does not make sense, because all galaxies are defined as collections of many (a billion or more) star systems, so a single star system cannot be larger than a galaxy.
24. *The universe is billions of light-years in age*. This statement does not make sense, because it uses the term "light-years" as a time, rather than as a distance.
25. *It will take me light-years to complete this homework assignment!* This statement does not make sense, because it uses the term "light-years" as a time, rather than as a distance.
26. *Someday we may build spaceships capable of traveling a light-year in only a decade*. This statement is fine. A light-year is the distance that light can travel in 1 year, so traveling this distance in a decade would require a speed of 10% of the speed of light.
27. *Astronomers recently discovered a moon that does not orbit a planet*. This statement does not make sense, because a moon is defined to be an object that orbits a planet.
28. *NASA will soon launch a spaceship that will photograph our Milky Way Galaxy from beyond its halo*. This statement does not make sense, because of the size scales involved: Even if we could build a spaceship that traveled close to the speed of light, it would take tens of thousands of years to get high enough into the halo to photograph the disk, and then tens of thousands of years more for the picture to be transmitted back to Earth.
29. *The observable universe is larger today than it was a few billion years ago*. This statement makes sense, because the size of the observable universe depends on the age of the universe, which means it must grow larger with time.
30. *Photographs of distant galaxies show them as they were when they were much younger than they are today*. This statement makes sense, because when we look far into space we also see far back in time. Thus, we see distant galaxies as they were in the distant past, when they were younger than they are today.
31. *At a nearby park, I built a scale model of our solar system in which I used a basketball to represent Earth*. This statement does not make sense. On a scale where Earth is the size of a basketball, we could not fit the rest of the solar system in a local park. (A basketball is roughly 200 times the diameter of Earth in the Voyage model described in the book. Since the Earth-Sun

distance is 15 meters in the Voyage model, a basketball-size Earth would require an Earth-Sun distance of about 3 kilometers and a Sun-Pluto distance of about 120 kilometers.)

32. *Because nearly all galaxies are moving away from us, we must be located near the center of the universe.* This statement does not make sense, as we can tell when we think about the raisin cake model. Every raisin sees every other raisin moving away from it, so in this sense no raisin is any more central than any other. (Equivalently, we could say that every raisin—or galaxy—is the center of its own observable universe, which is true but very different from the idea of an absolute center to the universe.)

Inclusive Astronomy/Process of Science

These are discussion-oriented questions, so we list only a few suggested things to look for in the student work.

33. Use this question to help direct your students to understanding and overcoming preconceptions they may have about scientists. It should be especially useful for students from backgrounds that are underrepresented in astronomy, as it should help them realize that people like them can be professional astronomers.

34. Major changes in scientific views are possible because science relies on physical evidence. Science must be backed by evidence from observations or experiments, and when the evidence contradicts the scientific story, the story is changed. That is what happened, for example, when belief in an Earth-centered universe gave way to the idea that Earth orbits the Sun. (In contrast, religious or cultural beliefs generally are less subject to change, because they are based on faith or scriptures rather than on a search for physical evidence.)

35. Using the Voyage model scale (1 to 10 billion), Earth is barely 1 millimeter across but is located 15 meters from the Sun. In other words, Earth's distance from the Sun is some 15,000 times as great as Earth's diameter. Given that fact, the difference in distance of the day and night sides of Earth is negligible, so it would be difficult to see how it could explain day and night temperature differences. If we had no other explanation for the temperature difference, then we might still be forced to consider whether there is some missing piece to our understanding. In this case, however, we have a much simpler alternative explanation: The day side is warm because it faces the Sun, and the night side is cooler because it faces away from the Sun.

36. Answers will vary based on the topic students choose. This question is designed to get students thinking about the nature of evidence and what it might take to get them to accept some scientific idea.

37. This is an opinion-based question, but look for students to show that they understand the chapter material when answering it.
38. This is an opinion-based question, but look for students to show that they understand the cosmic calendar when answering it.
39. This is group activity.

Short Answer/Essay Questions

40. This is a short essay question. Key points should include discussion of the difference in scale between interstellar travel and travel about our own world, so that students recognize that alien technology would have to be far more advanced than our own to allow them to visit us with ease.
41.
    a. The diagrams should be much like Figure 1.17, except that the distances between raisins in the expanded figure will be 4 centimeters instead of 3 centimeters.

    b.

    Distances and Speeds of Other Raisins as Seen from the Local Raisin

Raisin Number	Distance Before Baking	Distance After Baking (1 hour later)	Speed
1	1 cm	4 cm	3 cm/hr
2	2 cm	8 cm	6 cm/hr
3	3 cm	12 cm	9 cm/hr
4	4 cm	16 cm	12 cm/hr
⋮	⋮	⋮	⋮
10	10 cm	40 cm	30 cm/hr
⋮	⋮	⋮	⋮

    c. As viewed from any location inside the cake, more distant raisins appear to move away at faster speeds. This is much like what we see in our universe, where more distant galaxies appear to be moving away from us at higher speeds. Thus, we conclude that our universe, like the raisin cake, is expanding.
42.
    a. This problem asks students to draw a sketch. Using the scale of 1 centimeter = 100,000 light-years, the sketches should show that each of the two galaxies is about 1 centimeter in diameter and that the Milky Way and M31 are separated by about 25 centimeters.

b. The separation between the Milky Way and M31 is only about 25 times their respective diameters—and other galaxies in the Local Group lie in between. In contrast, the model solar system shows that, on a scale where stars are roughly the size of grapefruits, a typical separation is thousands of kilometers (at least in our region of the galaxy). Thus, while galaxies can collide relatively easily, it is highly unlikely that two individual stars will collide. *Note*: Stellar collisions are more likely in places where stars are much closer together, such as in the galactic center or in the centers of globular clusters.

43. This question asks students to learn about and write a short summary of how JWST's infrared observations are translated into visible images. In grading, be sure they have recognized that the general process involves assigning different visible colors to the various infrared wavelength bands observed by JWST.

44. This is a subjective essay question. Grade should be based on clarity of the essay.

Quantitative Problems

45.

a. A light-second is the distance that light travels in 1 second. We know that light travels at a speed of 300,000 kilometers per second, so a light-second is a distance of 300,000 kilometers.

b. A light-minute is the speed of light multiplied by 1 minute:

$$\begin{aligned}
&1 \text{ light-minute} = (\text{speed of light}) \times (1 \text{ min}) \\
&= 300{,}000 \frac{\text{km}}{\cancel{\text{s}}} \times 1 \cancel{\text{min}} \times \frac{60 \cancel{\text{s}}}{1 \cancel{\text{min}}} \\
&= 18{,}000{,}000 \text{ km}
\end{aligned}$$

That is, "1 light-minute" is just another way of saying "18 million kilometers."

c. Following a similar procedure, we find that 1 light-hour is 1.08 billion kilometers; and

d. 1 light-day is 2.59×10^{10} kilometers, or about 26 billion kilometers.

46. Recall that

$$\text{speed} = \frac{\text{distance traveled}}{\text{time of travel}}$$

We can solve for time by multiplying both sides by "time of travel" and dividing both sides by distance:

$$\text{time of travel} = \frac{\text{distance traveled}}{\text{speed}}$$

The speed of light is 3×10^5 kilometers per second. (We choose the value in kilometers per second rather than meters per second because we are given distances in kilometers.)

a. Mars at its nearest is 56 million kilometers away, so the light travel time is

$$\text{time of travel} = \frac{5.6 \times 10^7 \ \cancel{\text{km}}}{3.00 \times 10^5 \ \cancel{\text{km}}/\text{s}} = 187 \text{ s}$$

We would prefer this answer in minutes, so converting:

$$187 \ \cancel{\text{s}} \times \frac{1 \text{ min}}{60 \ \cancel{\text{s}}} = 3.11 \text{ min}$$

It takes a little over 3 minutes each way to communicate with a spacecraft on Mars at closest approach.

b. At the most distant, Mars is 400 million kilometers from Earth, so we can compute the travel time for light:

$$\text{time of travel} = \frac{4 \times 10^8 \ \cancel{\text{km}}}{3.00 \times 10^5 \ \cancel{\text{km}}/\text{s}} = 1330 \text{ s}$$

We would again prefer this in minutes, so we convert:

$$1330 \ \cancel{\text{s}} \times \frac{1 \text{ min}}{60 \ \cancel{\text{s}}} = 22.2 \text{ min}$$

It takes a little over 22 minutes each way to communicate with a spacecraft on Mars when Mars is at its farthest from Earth.

c. We will again use the speed-time-distance relationship:

$$\text{time of travel} = \frac{\text{distance traveled}}{\text{speed}}$$

In this case, we seek the time it takes light to travel from Earth to Pluto. Earth's average distance from the Sun is 1.496×10^8 kilometers and

Pluto's average distance is 5.916×10^9 kilometers. If we assume the two bodies are lined up on the same side of the Sun at their average distances, then the distance between them is

$$\begin{aligned}\text{Earth to Pluto distance} &= 5.916 \times 10^9 \text{ km} - 1.496 \times 10^8 \text{ km} \\ &= 5.766 \times 10^9 \text{ km}\end{aligned}$$

Using this value, the light travel time is

$$\text{time of travel} = \frac{5.766 \times 10^9 \cancel{\text{ km}}}{3.00 \times 10^5 \cancel{\text{ km}}/\text{s}} = 1.922 \times 10^4 \text{ s}$$

This is nearly 20,000 seconds, so let's try changing to more comprehensible units. We'll start by converting to minutes:

$$1.922 \times 10^4 \cancel{\text{ s}} \times \frac{1 \text{ min}}{60 \cancel{\text{ s}}} = 320 \text{ min}$$

That's a lot better, but it's still a lot more than 1 hour, so let's convert to hours:

$$320 \cancel{\text{ min}} \times \frac{1 \text{ hr}}{60 \cancel{\text{ min}}} = 5.33 \text{ hr}$$

It would take light 5.33 hours, or 5 hours and 20 minutes, to travel from Earth to Pluto under the alignment conditions and average distances we've assumed.

47. We are asked to find how many times larger the Milky Way Galaxy is than the planet Saturn's rings. We are told that Saturn's rings are about 270,000 kilometers across and that the Milky Way is 100,000 light-years in diameter. Clearly, we'll have to convert one set of units or the other. Let's change light-years to kilometers. In Appendix A we find that 1 $\text{light-year} = 9.46 \times 10^{12}$ kilometers, so we can convert:

$$100{,}000 \cancel{\text{ light-years}} \times \frac{9.46 \times 10^{12} \text{ km}}{1 \cancel{\text{ light-year}}} = 9.46 \times 10^{17} \text{ km}$$

We can now find the ratio of the two diameters:

$$\begin{aligned}\text{ratio} &= \frac{\text{diameter of Milky Way}}{\text{diameter of Saturn's rings}} \\ &= \frac{9.46 \times 10^{17} \cancel{\text{ km}}}{2.7 \times 10^5 \cancel{\text{ km}}} = 3.5 \times 10^{12}\end{aligned}$$

The diameter of the Milky Way Galaxy is about 3.5 trillion times as large as the diameter of Saturn's rings!

48. We are given the distance to Alpha Centauri as 4.4 light-years, but those units aren't very useful to us. So let's convert to kilometers. From Appendix A, we see that 1 $\text{light-year} = 9.46 \times 10^{12}$ kilometers. So the distance to Alpha Centauri is

$$4.4\ \cancel{\text{light-years}} \times \frac{9.46 \times 10^{12}\ \text{km}}{1\ \cancel{\text{light-year}}} = 4.2 \times 10^{13}\ \text{km}$$

At a scale of 1 to 10^{19}, the distance to Alpha Centauri is

$$\frac{4.2 \times 10^{13}\ \text{km}}{10^{19}} = 4.2 \times 10^{-6}\ \text{km}$$

As numbers go, that one's not very easy to picture. So let's convert it to some smaller units. Since there are a thousand (10^3) meters to a kilometer and a thousand (10^3) millimeters to a meter, there are (10^6) millimeters to a kilometer. Those units seem about right for this distance, so let's convert:

$$4.2 \times 10^{-6}\ \cancel{\text{km}} \times \frac{10^6\ \text{mm}}{1\ \cancel{\text{km}}} = 4.2\ \text{mm}$$

From Appendix E, the Sun is 7.0×10^5 kilometers in radius, so the diameter is twice this, or 1.4×10^6 kilometers. On the $1\text{-to-}10^{19}$ scale, this is

$$\frac{1.4 \times 10^6\ \text{km}}{10^{19}} = 1.4 \times 10^{-13}\ \text{km}$$

We're asked to compare this to the size of an atom, 10^{-10} meter, so we had better convert one of the numbers. We'll convert from kilometers to meters:

$$1.4 \times 10^{-13}\ \cancel{\text{km}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} = 1.4 \times 10^{-10}\ \text{m}$$

Note that this is about the same size as a typical atom. In summary, we've found that on a scale on which the Milky Way Galaxy would fit on a football field, the distance from the Sun to Alpha Centauri is only about 4.2 millimeters—smaller than the width of a finger—and the Sun itself becomes as small as an atom.

49.

a. First, we need to work out the conversion factor to use to go between the real universe and our model. We are told that the Milky Way Galaxy is to be about 1 centimeter in the new model. We know from this chapter that the Milky Way Galaxy is about 10^5 light-years across. We could convert this to kilometers, but looking at what we're asked to convert, it appears that all the numbers we'll be using will be given in light-years anyway. So our conversion factor is

$$1 \text{ cm} = 10^5 \text{ light-years}$$

So for the first part, we need to figure out how far the Andromeda Galaxy (also known as M31) is from the Milky Way. The chapter tells us that their actual separation is 2.5 million light-years. So the distance on our scale is

$$2.5 \times 10^6 \cancel{\text{ light-years}} \times \frac{1 \text{ cm}}{10^5 \cancel{\text{ light-years}}} = 25 \text{ cm}$$

The Andromeda Galaxy would be 25 centimeters away from our galaxy on this scale.

b. From Appendix F, we learn that Alpha Centauri is 4.4 light-years from the Sun. So using the conversion factor we developed in part (a), we convert this to the scale model distance:

$$4.4 \cancel{\text{ light-years}} \times \frac{1 \text{ cm}}{10^5 \cancel{\text{ light-years}}} = 4.4 \times 10^{-5} \text{ cm}$$

The separation between Alpha Centauri and our Sun is about 4.4×10^{-5} centimeter on this scale. As we will see in Chapter 5, this is comparable to the wavelength of deep blue light.

c. The observable universe is about 14 billion light-years in radius, so let's use that distance as an approximation to the distance of the most distant observable galaxies. Converting this distance to our model's scale:

$$14 \times 10^9 \cancel{\text{ light-years}} \times \frac{1 \text{ cm}}{10^5 \cancel{\text{ light-years}}} = 1.4 \times 10^6 \text{ cm}$$

That's more than a million centimeters, but it's difficult to visualize how far that is offhand. Let's convert that number to kilometers. We'll convert to meters first since we know how to go from centimeters to meters and meters to kilometers, but it's difficult to remember how to go straight from centimeters to kilometers:

$$1.4 \times 10^6 \cancel{\text{ cm}} \times \frac{1 \cancel{\text{ m}}}{100 \cancel{\text{ cm}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{ m}}} = 14 \text{ km}$$

On a scale where our entire Milky Way Galaxy is the size of a marble, the most distant galaxies in our observable universe would be located some 14 kilometers away.

50.

a. The circumference of Earth is $2\pi \times 6380 \text{ km} = 40{,}087 \text{ km}.$ At a speed of 100 kilometers per hour, it would take

$$40{,}087 \text{ km} \div 100 \text{ km/hr} = 40{,}087 \cancel{\text{km}} \times \frac{1 \cancel{\text{hr}}}{100 \cancel{\text{km}}} \times \frac{1 \text{ day}}{24 \cancel{\text{hr}}} = 16.7 \text{ days}$$

to drive around Earth. That is, a trip around the equator at 100 kilometers per hour would take a little under 17 days.

b. We find the time by dividing the distance to Earth from the Sun by the speed of 100 kilometers per hour. It would take about 170 years to reach Earth and about 6700 years to reach Pluto (at their mean distances).

c. Similarly, it would take 6700 years to drive from the Sun to Pluto at 100 kilometers per hour. FYI: The following table shows the driving times from the Sun to each of the planets at a speed of 100 kilometers per hour.

Planet	**Driving Time**
Mercury	66 yr
Venus	123 yr
Earth	170 yr
Mars	259 yr
Jupiter	888 yr
Saturn	1630 yr
Uranus	3300 yr
Neptune	5100 yr
Pluto	6700 yr

d. Appendix F gives the distance to Alpha Centauri in light-years; converting to kilometers, we get

$$4.4 \cancel{\text{light-years}} \times \frac{9.46 \times 10^{12} \text{ km}}{1 \cancel{\text{light-year}}} = 41.6 \times 10^{12} \text{ km}$$

At a speed of 100 kilometers per hour, the travel time to Alpha Centauri would be about

$$4.16\times10^{13}\ \text{km}\div100\frac{\text{km}}{\text{hr}}=4.16\times10^{13}\ \cancel{\text{km}}\times\frac{1\ \cancel{\text{hr}}}{100\ \cancel{\text{km}}}\times\frac{1\ \cancel{\text{day}}}{24\ \cancel{\text{hr}}}\times\frac{1\ \text{yr}}{365\ \cancel{\text{day}}}=4.7\times10^{7}\ \text{yr}$$

It would take some 47 million years to reach Alpha Centauri at a speed of 100 kilometers per hour.

51.

a. To reach Alpha Centauri in 100 years, you would have to travel at

$$\frac{4.4\ \cancel{\text{lt-yr}}\times9.46\times10^{12}\dfrac{\text{km}}{\cancel{\text{lt-yr}}}}{100\ \cancel{\text{yr}}\times365\dfrac{\cancel{\text{day}}}{\cancel{\text{yr}}}\times24\dfrac{\cancel{\text{hr}}}{\cancel{\text{day}}}\times60\dfrac{\cancel{\text{min}}}{\cancel{\text{hr}}}\times60\dfrac{\text{s}}{\cancel{\text{min}}}}\approx13220\frac{\text{km}}{\text{s}},$$

or nearly 50 million kilometers per hour. Note: An alternate (and perhaps easier) way to get this answer is to recognize that traveling 4.4 light-years in 100 years means traveling at 4.4% of the speed of light, or 0.44c. A unit conversion then gives the same answer of 13,200 km/hr.

b. This is about 1000 times the speed of our fastest current spacecraft.

52. The average speed of our solar system in its orbit of the Milky Way is the circumference of its orbit divided by the time it takes for one orbit:

$$v=\frac{2\pi(27{,}000\ \text{lt-yr})}{2.3\times10^{8}\ \text{yr}}=\frac{1.70\times10^{5}\ \cancel{\text{lt-yr}}\times9.46\times10^{12}\dfrac{\text{km}}{\cancel{\text{lt-yr}}}}{2.3\times10^{8}\ \cancel{\text{yr}}\times365\dfrac{\cancel{\text{day}}}{\cancel{\text{yr}}}\times24\dfrac{\text{hr}}{\cancel{\text{day}}}}\approx7.9\times10^{5}\frac{\text{km}}{\text{hr}}$$

We are racing around the Milky Way Galaxy at nearly 800,000 kilometers per hour.

53. We'll use the relationship that says that

$$\text{speed}=\frac{\text{distance traveled}}{\text{time}}$$

To compute each speed, we'll find the distance a person travels around Earth's axis in 1 day (24 hours). Using the hint from the problem, we can find that the radius of the circle that a person at a given latitude travels is $R_{\text{Earth}}\times\cos(\text{latitude})$, where $R_{\text{Earth}}=6378\ \text{km}$ from Appendix E.

a. The radius of the circle that a person at latitude 30°N travels is

$$(6378\ \text{km})\times\cos(30^\circ)=5524\ \text{km}$$

To get the distance traveled, we use the fact that a circle's circumference is given by $c = 2\pi r,$ so in this case:

$$\text{distance} = 2\pi(5524 \text{ km}) = 34{,}700 \text{ km}$$

Using the relationship between speed, time, and distance given above, the speed is

$$\text{speed} = \frac{34{,}700 \text{ km}}{24 \text{ hr}} = 1446 \text{ km/hr}$$

A person at $30°\text{N}$ latitude would be traveling at 1446 kilometers per hour around Earth's axis because of Earth's rotation.

b. The radius of the circle that a person at $60°\text{N}$ latitude travels is

$$(6378 \text{ km}) \times \cos(60°) = 3189 \text{ km}$$

The distance traveled is

$$\text{distance} = 2\pi(3189 \text{ km}) = 20{,}040 \text{ km}$$

The speed is

$$\text{speed} = \frac{20{,}040 \text{ km}}{24 \text{ hr}} = 834 \text{ km/hr}$$

A person at $60°\text{N}$ latitude travels around the axis at 834 kilometers per hour due to Earth's rotation.

c. Answers will vary depending on location.

54. The 1 trillion small galaxies would be 10 times as many as the number of large galaxies (100 billion) assumed in Mathematical Insight 1.3. However, the 10 million stars per galaxy in these small galaxies is only $1/10{,}000$ as many per galaxy as was assumed for the large galaxies. Therefore, these small galaxies would not make a significant difference to the calculation of the number of stars in the observable universe.

Note to Instructors

These test bank files are designed for you to be able to easily select and edit questions for exams. The files are organized by chapter, and you will note that each file consists of three main sections:

1. The set of multiple choice and short answer questions that are found in the Item Library as "test bank" questions. These are organized by section, along with a set assigned to "general chapter content" that either (1) use ideas from across the chapter, (2) ask students to extend ideas beyond the basics covered in the chapter, or (3) require mathematics from the Mathematical Insight boxes.
   Be sure to note that answers are included below each question; you'll obviously want to delete the answers before printing your exam.
   → Also note: These "test bank" questions are assignable through the Mastering Item Library by choosing the secondary book called "The Cosmic Perspective test bank."
2. The complete set of questions from the Reading, Concept, and Visual quizzes, which appear in the same format for student self-study in the Mastering Study Area. Note that these questions can also be found and assigned individually within the Item Library by selecting the question type "reading questions.
   Again, be sure to note that answers are included below each question; you'll obviously want to delete the answers before printing your exam.
3. The complete set of end-of-chapter questions from the textbook, which includes many questions that you can use for short answer or essays, as well as the multiple choice "quick quiz" questions and quantitative questions. Note: Some of the questions are designed for group work or discussion, so if you wish to use these on an exam, you will need to modify them so that they can be answered and graded.
   Answers/solutions to the end-of-chapter questions can be found in the Instructor's Guide, which is located in the Instructor Resource area of Mastering Astronomy.
   → These questions are also assignable through the Mastering Item Library.

We hope you will find these files useful as you construct your exams.

Jeff Bennett, Megan Donahue, Nick Schneider, Mark Voit

PS: While we've strived for all questions to be accurate and unambiguous, it is of course difficult to ensure that any test file is perfect. If you find any errors or ambiguities in any of the questions or answers, please send an email to Jeff Bennett (jeff@bigkidscience.com), so that we can update the files.

***The Cosmic Perspective, 10e* (Bennett)**
Chapter 1 A Modern View of the Universe

Section 1.1

1) About where is our solar system located within the Milky Way Galaxy?
A) at the center of the galaxy
B) about 10 percent of the way from the center of the galaxy to the edge of the galactic disk
C) about halfway from the center of the galaxy to the edge of the galactic disk
D) near the far edge of the galactic disk
E) in the halo of the galaxy above the galactic disk
Answer: C

2) When we speak of the entire universe (as opposed to the *observable* universe), we mean
A) all the stars and galaxies that we can see with telescopes.
B) all material located within about 14 billion light-years of Earth.
C) the sum total of all matter and energy.
D) all the matter in galaxies, but not the spaces between the galaxies.
Answer: C

3) Which of the following is the smallest distance?
A) diameter of a typical planet
B) 1 light-second
C) 1 AU
D) diameter of a typical star
Answer: A

4) Which of the following is the largest distance?
A) diameter of a typical galaxy
B) diameter of Pluto's orbit
C) distance to the nearest star (other than our Sun)
D) 1 light-year
Answer: A

5) Which of the following statements does *not* use the term *light-year* in an appropriate way?
A) It's about 4 light-years from here to Alpha Centauri.
B) It will take me light-years to complete this homework assignment.
C) A light-year is about 10 trillion kilometers.
D) It will take the Voyager spacecraft about 20,000 years to travel just 1 light-year.
E) The Milky Way Galaxy is about 100,000 light-years in diameter.
Answer: B

6) One *light-minute* is the distance that light travels in one minute. How far is this, in kilometers? (Recall that the speed of light is 300,000 km/s.)
A) 300,000 km
B) 18 million km
C) 100 million km
D) 1.08 billion km
E) 9.46 trillion km
Answer: B

7) One light-year is approximately
A) the distance from the Sun to Earth.
B) the speed at which Earth orbits the Sun.
C) 10 trillion kilometers.
D) the same as one regular year.
Answer: C

8) Light takes approximately one second to travel from Earth to the Moon. This means that the Moon is approximately
A) 1 astronomical unit from Earth.
B) 1 light-year from Earth.
C) 3000 kilometers from Earth.
D) 300,000 kilometers from Earth.
E) near the top of Earth's atmosphere.
Answer: D

9) Sunlight takes about 8.4 minutes to travel from the Sun to Earth. When NASA's *New Horizons* Spacecraft passed Pluto in 2015, it was about 32 AU from Earth. About how long did it take for transmitted images of Pluto to travel from the spacecraft to Earth?
A) one Plutonian year
B) 4-1/2 hours
C) 2-1/4 days
D) 3 weeks
E) They arrived almost instantaneously.
Answer: B

10) The *Voyager 2* Spacecraft is currently on its way out of our solar system at a speed of about 50,000 kilometers per hour. It will reach the distance of the nearest star system (beyond our solar system) in about ________ years.
A) 100
B) 1000
C) 10,000
D) 100,000
E) 1,000,000
Answer: D

11) Suppose we look at a photograph of many galaxies. Assuming that all galaxies formed at about the same time, which galaxy in the picture is the youngest?
A) the one that is farthest away
B) the one that is reddest in color
C) the one that is bluest in color
D) the one that is closest to us
E) the one that appears smallest in size
Answer: A

12) The farthest galaxies visible in photos from the James Webb Space Telescope are roughly ________ light-years away.
A) 1 million
B) 13 million
C) 1 billion
D) 13 billion
E) 13 trillion
Answer: D

13) Suppose we imagine the Sun to be about the size of a grapefruit. Which of the following best describes the size and distance of Earth on the same scale?
A) Earth is the size of a tip of a ballpoint pen about 1 meter from the Sun.
B) Earth is the size of a golf ball about 1 meter from the Sun.
C) Earth is the size of a tip of a ballpoint pen about 15 meters from the Sun.
D) Earth is the size of a golf ball about 15 meters from the Sun.
E) Earth is the size of a marble about 25 miles from the Sun.
Answer: C

14) Suppose we imagine the Sun to be about the size of a grapefruit. How big an area would the orbits of the eight planets of the solar system cover?
A) the size of a typical dorm room
B) the size of a typical campus building
C) the size of a typical campus
D) the size of a small city
E) the size of a western state (e.g., Colorado)
Answer: C

15) Which of the following best describes the Milky Way Galaxy?
A) a spiral galaxy with a disk about 100,000 light-years in diameter
B) a spiral galaxy with a disk about 1 billion kilometers in diameter
C) a spiral galaxy with a disk about 1000 light-years in diameter
D) a spherically shaped galaxy that is about 4 light-years in diameter
E) a spherically shaped galaxy that is about 100,000 light-years in diameter
Answer: A

16) If we use 1 millimeter to represent 1 light-year, about how large in diameter is the Milky Way Galaxy?
A) 100 millimeters
B) 100 meters
C) 1 kilometer
D) 100 kilometers
E) 1 million millimeters
Answer: B

17) How long would it take to count all the stars in the Milky Way Galaxy at a rate of one star per second?
A) several days
B) several weeks
C) several years
D) several thousand years
E) hundreds of thousands of years
Answer: D

18) About how many galaxies are there in the observable universe?
A) roughly (within about a factor of 10) the same as the number of stars in our galaxy
B) a few dozen
C) a few thousand
D) about as many as the number of grains of sand on all the beaches on Earth
E) an infinite number
Answer: A

19) If you represented each star by a grain of sand, about how much sand would it take to represent all the stars in the observable universe?
A) all the sand in a typical playground sandlot
B) all the sand on Miami Beach
C) all the sand on the beaches of California
D) one cubic meter of sand
E) all the sand on all the beaches on Earth
Answer: E

20) Suppose we look at two distant galaxies: Galaxy 1 is twice as far away as Galaxy 2. In that case
A) we are seeing Galaxy 1 as it looked at an earlier time in the history of the universe than Galaxy 2.
B) we can't say anything about these galaxies except for their distances.
C) we are seeing Galaxy 1 as it looked at a later time in the history of the universe than Galaxy 2.
Answer: A

21) The distance of Mars from the Sun is about 1.5 AU. How far is this in kilometers? (You do not need a calculator to answer this question. You do need to know what an AU is, within a factor of 1000.)
A) 1.5 × 150,000,000 km
B) 1.5 × 150,000 km
C) 150,000,000,000 / 1.5 km
D) 150,000,000 / 1.5 km
E) 1.5 × 150,000,000,000 km
Answer: A

Section 1.2

1) Shortly after the Big Bang, the chemical composition of the universe was
A) almost entirely hydrogen and helium.
B) hydrogen only.
C) about equal amounts of all the elements.
D) about the same as it is today.
Answer: A

2) About what percentage of the original hydrogen and helium of the universe had been converted into heavier elements by the time our solar system was born?
A) 20%
B) 10%
C) 50%
D) 2%
Answer: D

3) What is *nuclear fusion*?
A) an explosion caused by putting together two volatile chemicals
B) the process of splitting nuclei to produce energy
C) the process of turning matter into pure energy
D) the process of combining lightweight nuclei to make heavier nuclei
E) a process that only occurs in bombs
Answer: D

4) Earth is made mostly of metals and rocks. Where did most of the elements that make up these materials (carbon, silicon, iron, etc.) form?
A) They were produced by the Big Bang.
B) They were produced by chemical reactions in interstellar gas clouds.
C) They were produced by stars.
D) They were produced in our Sun.
E) They were produced by nuclear fission of uranium and other radioactive materials in space.
Answer: C

5) What did Carl Sagan mean when he said that we are *star stuff*?
A) The composition of most stars (mostly hydrogen and helium) is about the same as the composition of our bodies.
B) Cosmic rays reaching Earth from distant astronomical sources may be one source of mutations that help evolution along.
C) Nearly every atom from which we are made once (before the solar system formed) was inside of a star.
D) Nearly every atom from which we are made was once inside our star, the Sun.
E) Sagan thought that all of us have the potential to be movie (or TV) stars like he was.
Answer: C

6) The Sun is made primarily of
A) hydrogen and oxygen.
B) hydrogen and helium.
C) carbon and nitrogen.
D) oxygen and carbon.
E) nearly equal portions of all the elements.
Answer: B

7) Our Sun formed ________ our galaxy formed.
A) before
B) at the same time that
C) billions of years after
D) within about 10 million years after
Answer: C

8) In what sense are galaxies cosmic recycling plants?
A) Every time one star dies, a new one of exactly the same size and mass is born.
B) As a galaxy rotates, its stars cycle around the galaxy center again and again, each time returning to exactly where they started.
C) New stars in galaxies form from gas that has been ejected by previous generations of stars.
D) New galaxies are continuously being formed from the remains of older galaxies.
Answer: C

9) On the scale of the cosmic calendar, in which the history of the universe is compressed to 1 year, when did the Sun and Earth form?
A) January
B) December
C) September
D) February
Answer: C

10) On the scale of the cosmic calendar, in which the history of the universe is compressed to 1 year, how long has human civilization (i.e., since ancient Egypt) existed?
A) about half the year
B) about a month
C) a few hours
D) a few seconds
E) less than a millionth of a second
Answer: D

11) On the scale of the cosmic calendar, in which the history of the universe is compressed into 1 year, when did the dinosaurs become extinct?
A) in late December
B) in late November
C) in late October
D) in late September
E) in late August
Answer: A

12) On the scale of the cosmic calendar, in which the history of the universe is compressed into 1 year, when did Kepler and Galileo first discover that we live on a planet in a solar system?
A) 1 second ago
B) 1 day ago
C) 1 week ago
D) December 25
E) December 30
Answer: A

13) On the scale of the cosmic calendar, in which the history of the universe is compressed into 1 year, how long is the average human life span?
A) 0.2 millisecond
B) 0.2 second
C) 2 seconds
D) 2 minutes
E) 2 hours
Answer: B

14) Your textbook discusses the cosmic calendar, a model of the history of the universe scaled to a single year. The length of time represented by one month on this cosmic calendar is therefore closest to
A) 1 billion years.
B) 1 1000 years.
C) 10 million years.
D) 10 billion years.
E) 1 million years.
Answer: A

15) What made most of the oxygen nuclei in the solar system?
A) stars
B) Nothing makes elements—oxygen has always been present in the universe.
C) the Big Bang
D) our Sun
E) high energy collisions of dust and cosmic rays
Answer: A

Section 1.3

1) Approximately how fast is a person located at the Earth's equator moving around Earth's axis due to the rotation of the Earth?
A) 17,000 km/hr
B) 1700 km/hr
C) 170 km/hr
D) 17 km/hr
E) not moving at all
Answer: B

2) Earth's rotation causes a person at the North Pole to ________ relative to the center of the Earth.
A) move at a speed of about 1670 km/hr
B) spin in place once each year
C) remain completely stationary
D) spin in place once each day
Answer: D

3) The *ecliptic plane* is
A) the plane of Earth's orbit around the Sun.
B) the plane of the Moon's orbit around Earth.
C) the plane of our solar system's orbit around the Milky Way Galaxy.
D) a flat disk of material that lies between the Sun and Earth.
E) the plane defined by Earth's equator.
Answer: A

4) We say that Earth has an axis tilt of 23-1/2° because this is the angle between Earth's
A) rotation axis and a line perpendicular (vertical) to the ecliptic plane.
B) rotation axis and the star Polaris.
C) equator and rotation axis.
D) rotation axis and north pole.
E) rotation axis and magnetic axis.
Answer: A

5) Patterns of stars in constellations hardly change in appearance over times of even a few thousand years. Why?
A) Stars are fixed and never move.
B) Stars move, but they move very slowly—only a few kilometers in a thousand years.
C) Although most stars move through the sky, the brightest stars do not, and these are the ones that trace the patterns we see in the constellations.
D) The stars in our sky actually move rapidly relative to us—thousands of kilometers per hour—but are so far away that it takes a long time for this motion to make a noticeable change in the patterns in the sky.
E) Stars within a constellation move together as a group, which tends to hide their actual motion and prevent the pattern from changing.
Answer: D

6) About how long does it take our solar system to complete one orbit around the center of the Milky Way Galaxy?
A) 10,000 years
B) 1 million years
C) 230 million years
D) 4-1/2 billion years
E) 14 billion years
Answer: C

7) Which of the following correctly lists the described speeds from slowest to fastest?
A) Earth's orbital speed about the Sun
Earth's speed of rotation on its axis
Earth's orbital speed about the Sun
typical speeds of stars in the local solar neighborhood relative to us
the speed of our solar system orbiting the center of the Milky Way Galaxy
the speeds of very distant galaxies relative to us
B) typical speeds of stars in the local solar neighborhood relative to us
Earth's speed of rotation on its axis
Earth's orbital speed about the Sun
the speed of our solar system orbiting the center of the Milky Way Galaxy
the speeds of very distant galaxies relative to us
C) Earth's speed of rotation on its axis
Earth's orbital speed about the Sun
the speed of our solar system orbiting the center of the Milky Way Galaxy
the speeds of very distant galaxies relative to us
typical speeds of stars in the local solar neighborhood relative to us
D) Earth's orbital speed about the Sun
the speeds of very distant galaxies relative to us
Earth's speed of rotation on its axis
typical speeds of stars in the local solar neighborhood relative to us
the speed of our solar system orbiting the center of the Milky Way Galaxy
E) typical speeds of stars in the local solar neighborhood relative to us
the speed of our solar system orbiting the center of the Milky Way Galaxy
Earth's orbital speed about the Sun
the speeds of very distant galaxies relative to us
Earth's speed of rotation on its axis
Answer: A

8) What evidence leads astronomers to conclude that most of the Milky Way's mass consists of a mysterious *dark matter*?
A) We observe many dark clouds of gas that block the light of stars behind them.
B) The galaxy's rotation indicates that it must contain much more matter than we can observe with our telescopes.
C) Observations indicate that most stars are dimmer than the Sun, so we say they are "dark."
D) Stars are separated from one another by vast distances, and therefore most places in the galaxy would be dark to our eyes.
Answer: B

9) Most of the mass in the Milky Way Galaxy is located
A) in the halo (above/below the disk).
B) within the disk.
C) in the stars in the spiral arms.
D) in the gas and dust.
E) in the central bulge of the galaxy.
Answer: A

10) The amount and distribution of matter in the Milky Way Galaxy is determined by
A) counting the number of stars in the galaxy.
B) determining the amount of gas and dust in the galaxy.
C) studying where stars are located in the Milky Way.
D) studying the rotation of the galaxy.
E) adding together the mass of the galaxy's stars and gas.
Answer: D

11) What evidence leads astronomers to conclude that the universe contains a mysterious *dark energy?*
A) The expansion of the universe is accelerating with time.
B) The gravity of distant galaxies is stronger than that of galaxies nearby.
C) Studies of galactic motion indicate that there is more matter in the universe than we can account for with stars and gas.
D) Stars shine much more brightly than we would expect from nuclear fusion.
E) The existence of such dark energy is the only way to account for evil in the universe.
Answer: A

12) From the fact that virtually every galaxy is moving away from us and more distant galaxies are moving away from us at a faster rate than closer ones, we conclude that
A) the Milky Way Galaxy is expanding.
B) we are located at the center of the universe.
C) even nearby galaxies will eventually be moving faster than the speed of light.
D) the universe is expanding.
E) the universe is shrinking.
Answer: D

13) What do astronomers mean when they say the universe is expanding?
A) Everything in the universe is gradually growing in size.
B) Average distances are increasing between most galaxies.
C) Average distances are increasing between most stars.
D) The universe is expanding from a single point.
Answer: B

14) By studying distant galaxies in the 1920s, Hubble made the following important discovery that led us to conclude that the universe is expanding.
A) All galaxies contain billions of stars, and all galaxies have spiral shapes.
B) All galaxies were born at the same time, and all will die at the same time.
C) All galaxies outside the Local Group are moving away from us, and the farther away they are, the faster they're going.
D) All galaxies outside the Local Group are orbiting the Local Group.
E) Galaxies are in motion throughout the universe, with about equal numbers moving toward us and away from us.
Answer: C

15) Imagine that we put a raisin cake into the oven, with each raisin separated from the others by 1 cm. An hour later, we take it out and the distances between raisins are 3 cm. If you lived in one of the raisins and watched the other raisins as the cake expanded, which of the following would you observe?
A) All raisins would be moving away from you at the same speed.
B) More distant raisins would be moving away from you faster.
C) More distant raisins would be moving away from you more slowly.
D) It depends: If you lived in a raisin near the edge of the cake, you'd see other raisins moving away from you, but they'd be coming toward you if you lived in a raisin near the center of the cake.
E) The raisins would be expanding too, so you'd never notice any changes in the cake.
Answer: B

16) Recall the raisin cake model of the universe and its analogy to our expanding universe. Suppose you measure the recession velocity (the speed at which any object is moving away from us) of Galaxy A to be 2000 km/s and the recession velocity of Galaxy B to be 6000 km/s. What can you conclude about the relative distances of these two galaxies?
A) Galaxy A is 3 times as far from us as Galaxy B.
B) Galaxy B is 3 times as far from us as Galaxy A.
C) Galaxy A is 6 times as far from us as Galaxy B.
D) Galaxy B is 6 times as far from us as Galaxy A.
E) The relative distances cannot be determined from the information in this problem.
Answer: B

17) The reason that we observe more distant galaxies to be moving away from us at higher speeds than nearby galaxies is that
A) the more distant galaxies were flung outward faster by the Big Bang.
B) the more distant galaxies are smaller and less massive, so they can move faster.
C) the nearby galaxies are slowed by our own galaxy's gravitational pull.
D) there is more space to expand between us and the distant galaxies.
Answer: D

18) How do scientists estimate the age of the universe?
A) They look up the answer in a book or they Google it.
B) They measure the abundances of radioactive elements in meteorites, and use their half-lives to calculate the age of the meteorites, which are the oldest solids in the solar system.
C) They measure the speeds and distances of galaxies, and calculate the time it took for them to travel that distance (away from us).
D) They make a guess: no one really knows how old the universe is.
E) They measure how fast the Sun is losing energy, and how much energy it has left to lose.
Answer: C

19) According to astronomers, approximately how old is the universe?
A) 14 billion years
B) 14 trillion years
C) infinite
D) 14 million years
Answer: A

20) According to current scientific estimates, when did the Big Bang occur?
A) about 4.5 billion years ago
B) about 20 billion years ago
C) about 65 million years ago
D) about 14 billion years ago
E) about 10 billion years ago
Answer: D

21) We observe that most galaxies are moving away from us. If we could (somehow) communicate with an observer in a distant galaxy, what would that observer say about what it sees?
A) Most galaxies are moving away from me, except for yours.
B) Most galaxies are moving away from me, including yours.
C) Most galaxies are moving away from you, and about half are moving towards me.
Answer: B

General Chapter Questions

1) One light-year is the distance light travels in one year. The speed of light is about 300,000 km/s (3 s 10^5 km/s). How far is 1 light-year?
A) 3×10^5 km
B) 1.8×10^7 km
C) 1.08×10^9 km
D) 9.46×10^{12} km
Answer: D

2) Light travels at a speed of 300,000 km/s. About how far is a light-year?
A) 10 million meters
B) 10 billion km
C) 300,000 km
D) 10 million km
E) 10 trillion km
Answer: E

3) Consider how the Moon moves through the Solar System and complete the following sentence. The Moon orbits *the Sun*
A) once a month.
B) once a year.
C) once a day.
Answer: B

4) Suppose you know the speed of a spacecraft in kilometers per second. How would you calculate its speed in kilometers per hour?
A) Multiply by 60 and then multiply by 60 again.
B) Divide by 60 and then divide by 60 again.
C) Multiply by 24.
D) Divide by 24.
Answer: A

5) How many seconds are in one year? (Calculate this, do not look it up.)
A) about 380 million (380,000,000, or 3.8×10^8)
B) about 30 million (30,000,000, or 3×10^7)
C) about 86 thousand (86,000, or 8.6×10^5)
D) about 3600 (3.6×10^3)
Answer: B

6) One light-hour is the distance light travels in one hour. The speed of light is about 300,000 km/s (3×10^5 km/s). If Jupiter is 0.72 light hours from the Sun, how far is this?
A) 216 thousand km (2.16×10^5 km)
B) 13 million km (1.3×10^7 km)
C) 778 million km (7.78×10^8 km)
D) 1.5 billion km (1.5×10^9 km)
Answer: C

7) The planet Mars is, on average, about 228 million km from the Sun. How long does it take light from the Sun to reach Mars? (Recall that the speed of light is about 300,000 km/s.)
A) about 8.4 minutes
B) about 12.7 minutes
C) about 1.52 light seconds
D) about 1.52 hours
Answer: B

8) The Earth has a radius of about 6000 km. How long would it take for an object traveling at the speed of light to circle the Earth? (Recall that the speed of light is 300,000 km/s.)
A) 1/300,000 of a second (0.0000033 s)
B) 1/6000 of a second (0.000017 s)
C) 1/8 of a second (0.125 s)
D) 1/2 of a second (0.5 s)
Answer: C

9) Our solar system is located about 27,000 light-years from the galactic center. About how far does our solar system travel in one orbit?
A) 54,000 light-years
B) 85,000 light-years
C) 100,000 light-years
D) 170,000 light-years
Answer: D

10) Astronomer Alan says the universe is expanding at one rate and Astronomer Wendy says it is expanding at a faster rate. All other things being equal, which astronomer would say that the universe is *older*?
A) Wendy
B) Alan
C) neither
Answer: B

11) Astronomers have used observations from the Hubble Space Telescope to measure the rate at which the universe is expanding, and have estimated the age of the universe from that measured rate. Suppose that new evidence later shows that the expansion is *faster* than the Hubble Space Telescope measurements indicate. In that case, our new estimate for the age of the universe would be
A) unaffected.
B) younger (less time between now and the Big Bang).
C) older (more time between now and the Big Bang).
Answer: B

12) You observe two distant galaxies (well outside our Local Group of galaxies). You find that Galaxy W is moving away from us at a speed of 35,000 km/s and Galaxy X is moving away from us at a speed of 70,000 km/s. What can you say about the distances to those galaxies?
A) Galaxy W is four times as far as Galaxy X.
B) Galaxy W is twice as far as Galaxy X.
C) She can't say anything about the distances to Galaxy W or X.
D) Galaxy X is four times as far as Galaxy W.
E) Galaxy X is twice as far as Galaxy W.
Answer: B

Short Answer Questions

1) The speed of light is 300,000 km/s. How far is a light-year? Be sure to show all work clearly on your calculations.
Answer: 1 light-year
= (speed of light) × (1 yr)

$$= \left(300{,}000 \times \frac{\text{km}}{\text{s}}\right) \times \left(1\text{ yr} \times \frac{365}{1\text{ yr}} \times \frac{24}{1\text{ day}} \times \frac{60\text{ min}}{1\text{ hr}} \times \frac{60\text{s}}{1\text{ min}}\right)$$

= 9,460,000,000,000 km

2) Earth's actual diameter is about 12,800 kilometers. What is Earth's diameter in a 1-to-10 billion scale model solar system? Show your work clearly.
Answer: Scaled radius of Earth = actual radius/1010
$= 6{,}378\text{ km}/10^{10}$
$= 6{,}378 \times 105\text{ cm}/10^{10}$
$= 6.378 \times 10^{8}\text{ cm}/10^{10}$
$= 6.378 \times 10^{-2}\text{ cm}$
= 0.6 mm
This is about the size of the tip of a (fine tip) ballpoint pen.

Reading Quiz Questions

1) Which of the following is a general difference between a planet and a star?
A) Stars shine with energy released by nuclear fusion while planets shine primarily with light reflected from stars.
B) Stars are found in galaxies, but planets are not part of galaxies.
C) Stars are made of gas and planets are made of rock.
D) Stars are stationary while planets orbit stars.
Answer: A

2) Our solar system consists of ________.
A) the Sun and all the objects that orbit it
B) the Sun and the planets, and nothing else
C) a few hundred billion stars, bound together by gravity
D) the Sun and several nearby stars, as well as the planets and other objects that orbit these stars
Answer: A

3) A typical galaxy is a ________.
A) collection of millions or billions of stars, bound together by gravity and orbiting a common center
B) large, glowing ball of gas powered by nuclear energy
C) nearby object orbiting a planet
D) relatively small, icy object orbiting a star
E) system consisting of one or a few stars orbited by planets, moons, and smaller objects
Answer: A

4) Which of the following best describes what we mean by the term *universe*?
A) the sum total of all matter and energy
B) a vast collection of stars that number as many as the grains of sand on all the beaches on Earth
C) all the galaxies in all the superclusters
D) our Milky Way Galaxy
Answer: A

5) An astronomical unit (AU) is ________.
A) any very large unit, such as a light-year
B) the *average* distance between Earth and the Sun
C) the *current* distance between Earth and the Sun
D) the average distance between any planet and the Sun
Answer: B

6) A *light-year* is ________.
A) about 10 trillion kilometers
B) the time it takes light to reach the nearest star
C) the time it takes light to travel around the Sun
D) about 300,000 kilometers per second
Answer: A

7) A television advertisement claiming that a product is light-years ahead of its time does not make sense because ________.
A) it doesn't specify the number of light-years
B) it uses "light-years" to talk about time, but a light-year is a unit of distance
C) a light-year is an astronomically large unit, so a product could not possibly be so advanced
D) light-years can only be used to talk about light
Answer: B

8) The term *observable universe* refers to ________.
A) the portion of the universe that we have so far photographed through telescopes
B) the portion of the universe that can be seen by the naked eye
C) the portion of the universe that is not hidden from view by, for example, being below the horizon
D) the portion of the universe that we can see *in principle*, given the current age of the universe
Answer: D

9) On a scale where the distance from Earth to the Sun is about 15 meters, the distance from Earth to the Moon is ________.
A) small enough to fit within your hand
B) about 1 meter
C) about 5 meters
D) about 30 meters
Answer: A

10) On a scale where the Sun is about the size of a grapefruit and the Earth is about 15 meters away, how far away are the nearest stars besides the Sun?
A) 100 meters
B) About the distance across 50 football fields
C) About the distance across the state of Delaware
D) About the distance across the United States
Answer: D

11) The number of stars in the Milky Way Galaxy is approximately ________.
A) a few hundred
B) a few hundred thousand
C) a few hundred billion
D) a few hundred million
Answer: C

12) What do astronomers mean by the *Big Bang*?
A) the event that marked the beginning of the expansion of the universe
B) a gigantic explosion that blew all the galaxies in the universe to smithereens
C) the explosion of a massive star at the end of its life
D) the event that marked the birth of our solar system
Answer: A

13) What do we mean when we say that the universe is *expanding*?
A) Everything in the universe is gradually growing in size.
B) Within galaxies, average distances between star systems are increasing with time.
C) The statement is not meant to be literal; rather, it means that our knowledge of the universe is growing.
D) Average distances between galaxies are increasing with time.
Answer: D

14) Based on observations of the universal expansion, the age of the universe is about ________.
A) 14,000 years
B) 14 million years
C) 14 billion years
D) 14 trillion years
Answer: C

15) If the 14 billion year history of the universe were compressed to one year, and "now" is exactly midnight December 31, approximately how long ago were your grandparents born?
A) 0.15 second ago
B) 1 second ago
C) 1 minute ago
D) 1 hour ago
Answer: C

16) What is the *ecliptic plane*?
A) the plane of Earth's orbit around the Sun
B) the plane of Earth's equator
C) the plane of the Sun's equator
D) the plane of the Milky Way Galaxy
Answer: A

17) How long does it take the Earth to complete one orbit around the Sun?
A) one year
B) one day
C) one month
D) one week
E) The time it takes Earth to orbit the Sun changes significantly from one orbit to the next.
Answer: A

18) What is the "raisin cake analogy" to the expanding universe intended to explain?
A) That as a raisin cake expands, every raisin moves away from every other raisin, just as galaxies move away from each other in an expanding universe.
B) That raisins, like galaxies, expand in size as the cake or universe expands.
C) That from within the raisin cake, you would see other raisins moving away from you only if you were on the central raisin, just as you see galaxies moving away only if you are in the center of the universe.
D) That the universe heats up as it expands, just as the raisin cake heats up as it bakes.
Answer: A

Concept Quiz Questions

1) Which of the following has your "cosmic address" in the correct order?
A) You, Earth, solar system, Local Group, Local Supercluster, Milky Way Galaxy, universe
B) You, Earth, solar system, Milky Way Galaxy, Local Group, Local Supercluster, universe
C) You, Earth, Local Group, Local Supercluster, solar system, Milky Way Galaxy, universe
D) You, Earth, solar system, Local Group, Milky Way Galaxy, Local Supercluster, universe
E) You, Earth, Milky Way Galaxy, solar system, Local Group, Local Supercluster, universe
Answer: B

2) When we look at an object that is 1,000 light-years away we see it ________.
A) as it was 1,000 years ago
B) as it was 1,000 light-years ago
C) as it is right now, but it appears 1,000 times dimmer
D) looking just the same as our ancestors would have seen it 1,000 years ago
Answer: A

3) Suppose that Galaxy 1 is twice as far away from us as Galaxy 2. Which of the following must be true?
A) Galaxy 1 is twice as big as Galaxy 2
B) We are seeing Galaxy 1 as it looked at an *earlier* time in the history of the universe than Galaxy 2.
C) We are seeing Galaxy 1 as it looked at a *later* time in the history of the universe than Galaxy 2.
D) Galaxy 2 is twice as old as Galaxy 1
Answer: B

4) Could we see a galaxy that is 20 billion light-years away? (Assume that we mean a "lookback time" of 20 billion years.)
A) No, because it would be beyond the bounds of our observable universe.
B) Yes, if we had a big enough telescope.
C) No, because a galaxy could not possibly be that far away.
D) Yes, we have already detected galaxies at that distance.
Answer: A

5) Suppose we make a scale model of our solar system, with the Sun the size of a grapefruit. Which of the following best describes what the planets would look like?
A) The planets are all much smaller than the Sun. Four planets are within about 20 meters of the Sun, while the rest planets are spread much farther apart.
B) The planets are all much smaller than the Sun and are spread out evenly over a distance about the length of a large classroom.
C) The planets are all much smaller than the Sun. Four planets are located within a few centimeters of the Sun, and four planets are located at distances ranging up to about a meter.
D) The planets range in size from about the size of a marble to the size of a baseball. They are spread out over a region about the size of a football field.
Answer: A

6) If you could count stars at a rate of about one per second, how long would it take to count all the stars in the Milky Way Galaxy?
A) Several days
B) Several weeks
C) Several years
D) Several thousand years
Answer: D

7) The total number of stars in the observable universe is about ________.
A) 100 billion
B) the same as the number of grains of sand in a school sandbox
C) the same as the number of grains of sand on all the beaches on Earth
D) the same as the number of atoms that make up the Earth
Answer: C

8) Using the ideas discussed in your text, in what sense are we "star stuff?"
A) The overall chemical composition of our bodies is about the same as that of stars.
B) Movie stars and other people are all made of the same stuff, so we all have the potential to be famous.
C) Nearly every atom from which we are made was once inside of a star.
D) We could not survive without light from our star, the Sun.
Answer: C

9) How are galaxies important to our existence?
A) Without galaxies, there could not have been a Big Bang.
B) Without galaxies, the universe could not be expanding.
C) Deep in their centers, galaxies created the elements from which we are made.
D) Galaxies recycle material from one generation of stars to the next, and without this recycling, we could not exist.
Answer: D

10) If we imagine the history of the universe compressed into one year, with the present as the stroke of midnight at the very end of that year, dinosaurs became extinct ________.
A) about 6 months ago
B) about 3 weeks ago
C) yesterday morning
D) about an hour ago
Answer: C

11) Relative to the age of the universe, how old is our solar system?
A) It is about 1% as old as the universe.
B) It is between about 5 and 10% as old as the universe.
C) It is about one third the age of the universe.
D) It is nearly the same age as the universe.
Answer: C

12) Which of the following statements is true about the speeds at which we are moving with Earth's rotation and orbit?
A) Earth's rotation carries most people around the axis faster than a commercial jet travels, and Earth's orbit carries us around the Sun faster than the Space Station orbits Earth.
B) Earth's rotation carries most people around the axis at about the speed of a commercial jet, and Earth's orbit carries us around the Sun at about the speed of a military jet.
C) Earth's rotation carries most people around the axis at about the speed of a car on the freeway, and Earth's orbit carries us around the Sun at about the speed of a commercial jet.
D) Earth's rotation carries most people around the axis at about the speed at which the Space Station orbits Earth, and Earth's orbit carries us around the Sun at nearly the speed of light.
Answer: A

13) Why do the patterns of the stars in our sky look the same from year to year?
A) Because the stars in the constellations are so far away.
B) Because the stars in the constellations are not moving.
C) Because the stars in the constellations all move at the same speeds and in the same directions, so they don't change their relative positions.
D) Because the stars in the constellations typically move so slowly --- typically about the speed of a snail --- that their motions are not noticeable.
Answer: A

14) Where is our solar system located within the Milky Way Galaxy?
A) Very near the center of the galaxy
B) At the far edge of the galaxy's visible disk
C) Roughly halfway between the center and the edge of the visible disk of the galaxy
D) In the halo of the galaxy
Answer: C

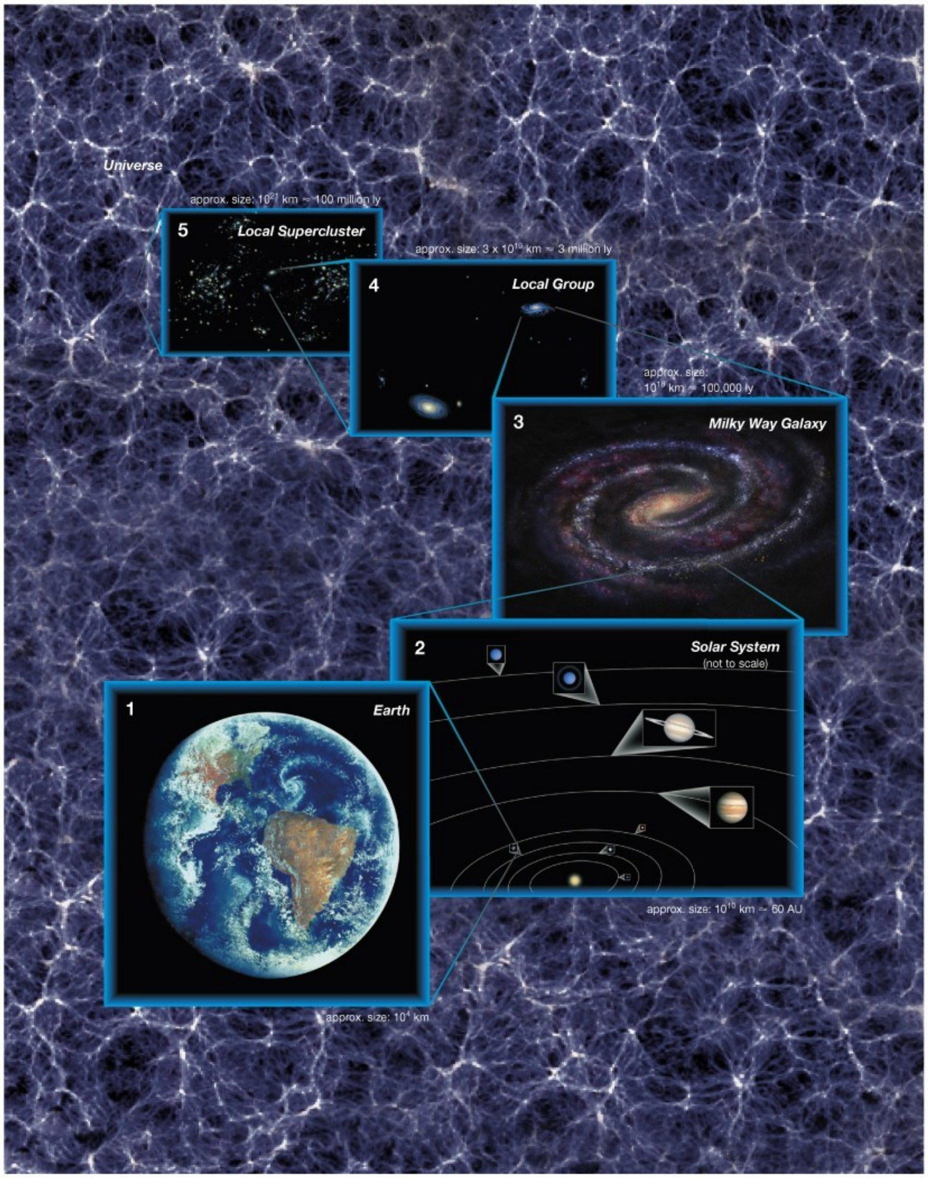
15) Consider a raisin cake expanding uniformly in an oven. Viewed from one of the raisins, you would see ________.
A) all other raisins moving away from you, with more distant raisins moving faster
B) all other raisins moving away from you, with more distant raisins moving slower
C) all other raisins moving away from you at the same speed
D) all raisins, including your own, growing in size as the cake expands
Answer: A

16) Astronomers infer that the universe is expanding because distant galaxies all appear to ________.
A) be growing in size
B) be moving away from us, with more distant ones moving faster
C) be made mostly of dark matter
D) rotate rapidly
Answer: B

17) Which statement about motion in the universe is *not* true?
A) The mysterious *dark matter* is the fastest-moving material in the universe.
B) Some stars in the Milky Way Galaxy are moving toward us and others are moving away from us.
C) Except for a few nearby galaxies, all other galaxies are moving away from us.
D) Your speed of rotation around Earth's axis is faster if you live near the equator than if you live near the North Pole.
Answer: A

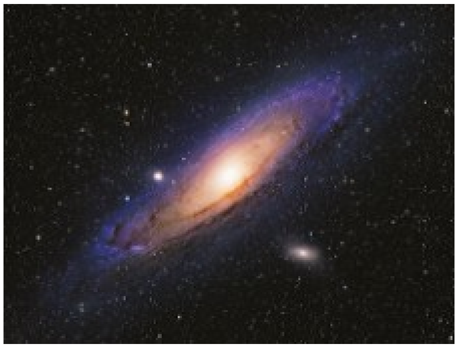
Visual Quiz Questions

1) Each box in this figure represents a different level of structure in our universe. Each box is labeled with one of the numbers 1—5. Which box represents the Milky Way Galaxy?



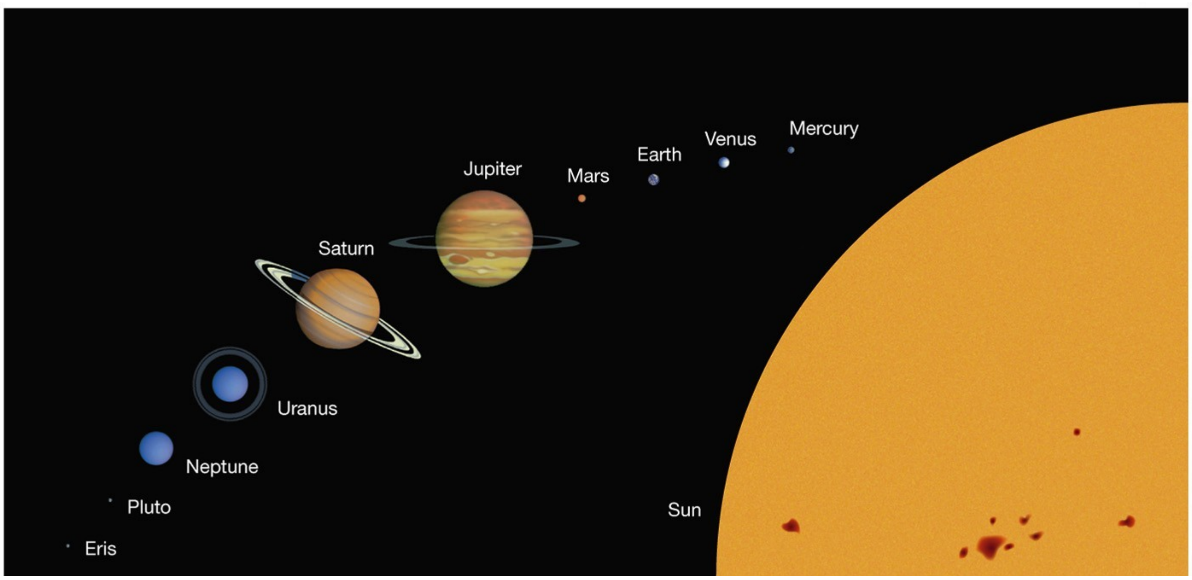
A) 1
B) 2
C) 3
D) 4
E) 5
Answer: C

2) What does this photograph show?



A) It is a picture of our own Milky Way Galaxy.
B) It is a picture of the Andromeda galaxy, located about 2.5 million light-years away.
C) It is a picture of a cloud of gas known as the Orion Nebula.
D) It is a picture of our own solar system.
E) It is a picture of a young star in the process of being born.
Answer: B

3) This painting represents the Sun and planets (and two dwarf planets) of our solar system. What is *not* to scale in this painting?

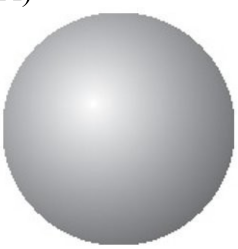


A) The sizes of the planets are not correctly scaled compared to each other or the Sun.
B) The distances between the planets are not shown to scale.
C) The Sun is too big compare to the planets.
D) Everything is correctly scaled, but the planets are shown in the wrong order from the Sun.
E) Neither distances nor sizes are correctly scaled.
Answer: B

4) What is the significance of this photograph?

A) It shows the first person ever to land on Mars.
B) It shows a person standing on the most distant world ever visited by a human being.
C) It shows the first person ever to go into space.
D) It was taken Jan. 1, 2000, to commemorate the turn of the millennium.
Answer: B

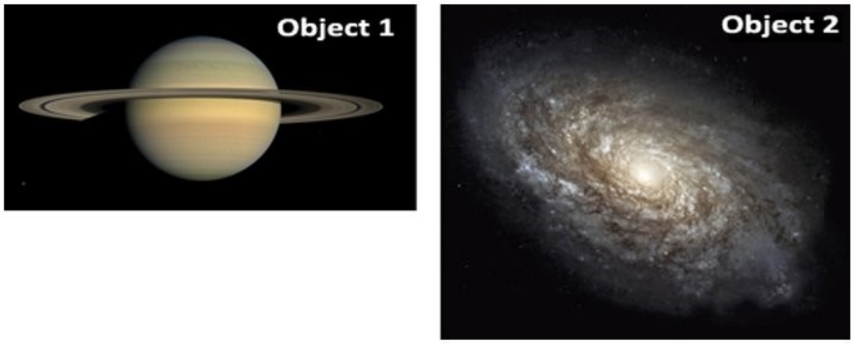
5) Suppose we made a scale model of our Milky Way Galaxy in which the disk of the galaxy is the size of a football field. Which (if any) diagram represents the Sun on the same scale?
A)



B)

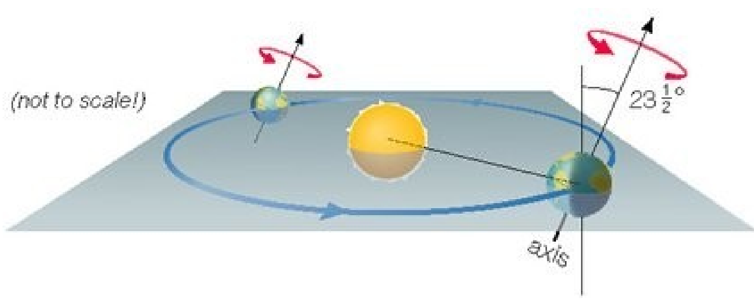
C)
D) The Sun on this scale would be about two feet in diameter and too big to show on the screen.
E) The Sun on this scale would be microscopic and too small to see on the screen.
Answer: E

6) These photos show two different astronomical objects. Which object is bigger, and by about how much?



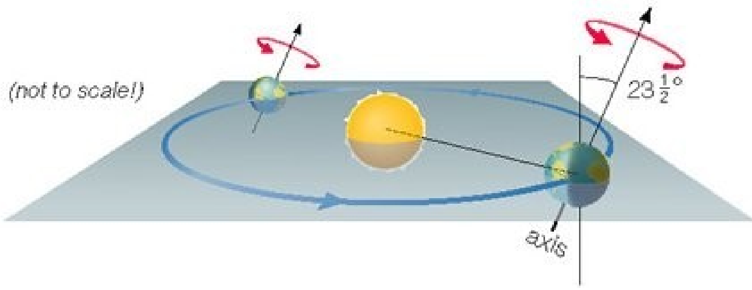
A) Object 2 is more than a trillion times as large as Object 1.
B) Object 2 is approximately 1,000 times as large as Object 1.
C) Object 2 is about 10 times as large as Object 1.
D) Object 1 is about 10 times as large as Object 2.
E) Both objects are about the same size.
Answer: A

7) This diagram represents Earth's rotation and orbit. What do we call the flat blue plane shown in this diagram?



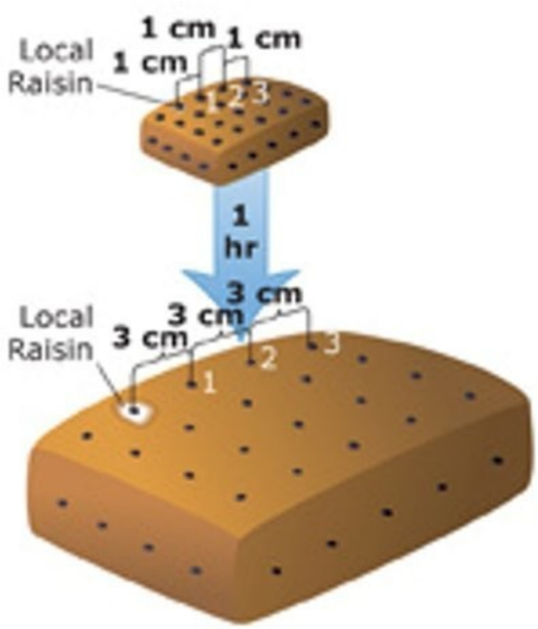
A) the solar plane
B) the ecliptic plane
C) Earth's axis
D) the galactic plane
E) an astronomical unit
Answer: B

8) Notice that Earth's axis is shown with an arrowhead in this diagram. What does the arrow point to?



A) the Sun
B) the ecliptic plane
C) the center of the Milky Way Galaxy
D) Polaris, the North Star
E) the Northern lights
Answer: D

9) These diagrams show a raisin cake before it is put in the oven and again one hour later after it has expanded during baking. Suppose you lived in Raisin 3 (the raisin labeled "3"). What would you have noticed about Raisin 2 during baking?



A) Raisin 2 is moving away from you at a speed of 4 cm/hr.
B) Raisin 2 always stays in the same place but gets bigger in size.
C) Raisin 2 is moving away from you at a speed of 2 cm/hr.
D) Raisin 2 is moving away from you at a speed of 6 cm/hr.
E) Raisin 2 is moving toward you at a speed of 2 cm/hr.
Answer: C

10) Nearly all of the objects that you can see in this photograph are:

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A) planets
B) stars
C) galaxies
D) astronomical units
Answer: C

End-of-Chapter Questions

Visual Skills Check
Use the following questions to check your understanding of some of the many types of visual information used in astronomy.

Useful Data:

Earth -sum distance	= 150,000,000 km
Diameter of sun	= 1,400,000 km
Earth-Moon distance	= 384,000 km
Diameter of Earth	= 12,800 km

The figure above shows the sizes of Earth and the Moon to scale; the scale used is 1 cm = 4000 km. Using what you've learned about astronomical scale in this chapter, answer the following questions. Hint: If you are unsure of the answers, you can calculate them using the data given above.

1) If you wanted to show the *distance* between Earth and the Moon on the same scale, about how far apart would you need to place the two photos?
A) 10 centimeters (about the width of your hand)
B) 1 meter (about the length of your arm)
C) 100 meters (about the length of a football field)
D) 1 kilometer (a little more than a half mile)
Answer: B

2) Suppose you wanted to show the Sun on the same scale. About how big would it need to be?
A) 3.5 centimeters in diameter (the size of a golf ball)
B) 35 centimeters in diameter (a little bigger than a basketball)
C) 3.5 meters in diameter (about 11½ feet across)
D) 3.5 kilometers in diameter (the size of a small town)
Answer: C

3) About how far away from Earth would the Sun be located on this scale?
A) 3.75 meters (about 12 feet)
B) 37.5 meters (about the height of a 12-story building)
C) 375 meters (about the length of four football fields)
D) 37.5 kilometers (the size of a large city)
Answer: C

4) Could you use the same scale to represent the distances to nearby stars? Why or why not?
Answer: No. The nearest stars would not fit on Earth using this scale. The total distance to the nearest star would wrap around the Earth about 2.5 times!

Exercises and Problems

Quick Quiz
Start with these questions as a quick test of your general understanding. Choose the best answer in each case, and explain your reasoning.

1) Which of the following correctly lists our "cosmic address" from small to large?
A) Earth, solar system, Milky Way Galaxy, Local Group, Local Supercluster, universe
B) Earth, solar system, Local Group, Local Supercluster, Milky Way Galaxy, universe
C) Earth, Milky Way Galaxy, solar system, Local Group, Local Supercluster, universe
Answer: A

2) An astronomical unit is
A) any planet's average distance from the Sun.
B) Earth's average distance from the Sun.
C) any large astronomical distance.
Answer: B

3) The star Betelgeuse is about 600 light-years away. If it explodes tonight,
A) we'll know because it will be brighter than the full Moon in the sky.
B) we'll know because debris from the explosion will rain down on us from space.
C) we won't know about it until about 600 years from now.
Answer: C

4) If we represent the solar system on a scale that allows us to walk from the Sun to Pluto in a few minutes, then
A) the planets are the size of basketballs and the nearest stars are a few miles away.
B) the planets are marble-size or smaller and the nearest stars are thousands of miles away.
C) the planets are microscopic and the stars are light-years away.
Answer: B

5) The total number of stars in the observable universe is roughly equivalent to
A) the number of grains of sand on all the beaches on Earth.
B) the number of grains of sand on Miami Beach.
C) infinity.
Answer: A

6) When we say the universe is expanding, we mean that
A) everything in the universe is growing in size.
B) the average distance between galaxies is growing with time.
C) the universe is getting older.
Answer: B

7) If stars existed but galaxies did not,
A) we would probably still exist anyway.
B) we would not exist because life on Earth depends on the light of galaxies.
C) we would not exist because we are made of material that was recycled in galaxies.
Answer: C

8) Could we see a galaxy that is 50 billion light-years away?
A) Yes, if we had a big enough telescope.
B) No, because it would be beyond the bounds of our observable universe.
C) No, because a galaxy could not possibly be that far away.
Answer: B

9) The age of our solar system is about
A) one-third of the age of the universe.
B) three-fourths of the age of the universe.
C) 2 billion years less than the age of the universe.
Answer: A

10) The fact that nearly all galaxies are moving away from us, with more distant ones moving faster, helped us to conclude that
A) the universe is expanding.
B) galaxies repel each other like magnets.
C) our galaxy lies near the center of the universe.
Answer: A

Chapter Review Questions
You should be able to answer these questions by re-reading portions of the chapter as needed.

11) Briefly describe the major levels of structure (such as planet, star, galaxy) in the universe.

12) Define *astronomical unit* and *light-year*.

13) Explain the statement "*The farther away we look in distance, the further back we look in time*."

14) What do we mean by the *observable universe*? Is it the same thing as the entire universe?

15) Using techniques described in the chapter, put the following into perspective: the size of our solar system; the distance to nearby stars; the size and number of stars in the Milky Way Galaxy; the number of stars in the observable universe.

16) What do we mean when we say that the universe is *expanding*, and how does expansion lead to the idea of the *Big Bang* and our current estimate of the age of the universe?

17) In what sense are we "star stuff"?

18) Use the cosmic calendar to describe how the human race fits into the scale of time.

19) Briefly explain Earth's daily rotation and annual orbit, defining the terms *ecliptic plane* and *axis tilt*.

20) Briefly describe our solar system's location and motion within the Milky Way Galaxy.

21) Why do scientists suspect that most of our galaxy's mass consists of *dark matter*? Briefly describe the mystery of dark matter and *dark energy*.

22) What key observations lead us to conclude that the universe is expanding? Use the raisin cake model to explain how these observations imply expansion.

Think Critically

Does it make sense? Decide whether or not each of the following statements makes sense (or is clearly true or false). Explain clearly; not all of these have definitive answers, so your explanation is more important than your chosen answer.

Example: I walked east from our base camp at the North Pole.

Solution: The statement does not make sense because east has no meaning at the North Pole -all directions are south from the North Pole.

23) Our solar system is bigger than some galaxies.

24) The universe is billions of light-years in age.

25) It will take me light-years to complete this homework assignment!

26) Someday we may build spaceships capable of traveling a light-year in only a decade.

27) Astronomers recently discovered a moon that does not orbit a planet.

28) NASA will soon launch a spaceship that will photograph our Milky Way Galaxy from beyond its halo.

29) The observable universe is larger today than it was a few billion years ago.

30) Photographs of distant galaxies show them as they were when they were much younger than they are today.

31) At a nearby park, I built a scale model of our solar system in which I used a basketball to represent Earth.

32) Because nearly all galaxies are moving away from us, we must be located near the center of the universe.

Inclusive Astronomy
Use these questions to reflect on participation in science.

33) *Group Discussion: What does a scientist look like?* The purpose of this exercise is to help you identify preconceptions that you or others may have about science and scientists.
a) Working independently, make a simple sketch of a professional scientist and write down five words that describe the scientist in your sketch. Then join with a group of two to three other students to share your sketches and word lists.
b) Make a list of all the words the group wrote down, then rank them in order of how often they were used.
c) Discuss any similarities, differences, or patterns you notice among the scientists described by the group members.
d) Discuss whether you and the other members of your group feel as if you have much in common with professional scientists.
e) Discuss how your beliefs about what you have (or do not have) in common with scientists might affect your approach to scientific thinking.

The Process of Science
These questions may be answered individually in short-essay form or discussed in groups, except where identified as group-only.

34) *Earth as a Planet.* For most of human history, scholars assumed Earth was the center of the universe. Today, we know that our Sun is just one star in a vast universe. How did science make it possible for us to learn these facts about Earth?

35) *Thinking About Scale.* One key to success in science is finding simple ways to evaluate new ideas, and making a simple scale model is often helpful. Suppose someone tells you that the reason it is warmer during the day than at night is that the day side of Earth is closer to the Sun than the night side. Evaluate this idea by thinking about the size of Earth and its distance from the Sun in a scale model of the solar system.

36) *Looking for Evidence.* In this first chapter, we have discussed the scientific story of the universe but have not yet discussed most of the evidence that backs it up. Choose one idea presented in this chapter–such as the idea that there are billions of galaxies in the universe, or that the universe was born in the Big Bang, or that the galaxy contains more dark matter than ordinary matter–and briefly discuss the type of evidence you would want to see before accepting the idea. (*Hint*: It's okay to look ahead in the book to see the evidence presented in later chapters.)

37) *A Human Adventure.* Astronomical discoveries clearly are important to science, but are they also important to our personal lives? Defend your opinion.

38) *Infant Species.* In the last few tenths of a second before midnight on December 31 of the cosmic calendar, we have developed an incredible civilization and learned a great deal about the universe, but we also have developed technology with which we could destroy ourselves. The midnight bell is striking, and the choice for the future is ours. How far into the next cosmic year do you think our civilization will survive? Defend your opinion.

39) *Group Activity: Counting the Milky Way's Stars.* Work as a group to answer each part. *Note*: This activity works particularly well in groups of four students, with each student taking on one of the following roles: *Scribe*–takes notes on the group's activities; *Proposer*–suggests tentative explanations to the group; *Skeptic*–points out weaknesses in proposed explanations; *Moderator*–leads group discussion and makes sure everyone contributes.
a) Work together to estimate the number of stars in the Milky Way from just these two facts: (1) the number of stars within 12 light-years of the Sun, which you can count in Appendix F; (2) the total volume of the Milky Way's disk (100,000 light-years in diameter and 1000 light-years thick), which is about 1 billion times the volume of the region of your star count.
b) Discuss how your value from part a compares to the value given in this chapter. Make a list of possible reasons why your technique may have underestimated or overestimated the actual number.

Investigate Further
Short-Answer/Essay Questions

40) *Alien Technology.* Some people believe that Earth is regularly visited by aliens who travel here from other star systems. For this to be true, how much more advanced than our own technology would the alien space travel technology have to be? Write one to two paragraphs to give a sense of the technological difference. (*Hint*: The ideas of scale in this chapter can help you contrast the distance the aliens would have to travel with the distances we currently are capable of traveling.)

41) *Raisin Cake Universe.* Suppose that all the raisins in a cake are 1 centimeter apart before baking and 4 centimeters apart after baking.
a) Draw diagrams to represent the cake before and after baking.
b) Identify one raisin as the Local Raisin on your diagrams. Construct a table showing the distances and speeds of other raisins as seen from the Local Raisin.
c) Briefly explain how your expanding cake is similar to the expansion of the universe.

42) *Scaling the Local Group of Galaxies.* Both the Milky Way Galaxy and the Andromeda Galaxy (M31) have a diameter of about 100,000 light-years. The distance between the two galaxies is about 2.5 million light-years.
a) Using a scale on which 1 centimeter represents 100,000 light-years, draw a sketch showing both galaxies and the distance between them to scale.
b) How does the separation between galaxies compare to the separation between stars? Based on your answer, discuss the likelihood of galactic collisions in comparison to the likelihood of stellar collisions.

43) *Coloring the Universe.* The photo that opens this chapter comes from the James Webb Space Telescope (JWST), which observes infrared light that is invisible to our eyes. This means that the colors you see in the photo are not "real" but rather represent different wavelengths of infrared light. Visit the JWST web site to learn how scientists "translate" the infrared light detected by the telescope into colors like those you see in the photo. Write a short summary of your findings.

44) *The Cosmic Perspective.* Write a short essay describing how the ideas presented in this chapter affect your perspectives on your own life and on human civilization.

Quantitative Problems

Be sure to show all calculations clearly and state your final answers in complete sentences.

45) *Distances by Light.* Just as a light-year is the distance that light can travel in 1 year, we define a light-second as the distance that light can travel in 1 second, a light-minute as the distance that light can travel in 1 minute, and so on. Calculate the distance in both kilometers and miles represented by each of the following:
a) 1 light-second.
b) 1 light-minute.
c) 1 light-hour.
d) 1 light-day.

46) *Spacecraft Communication.* We use radio waves, which travel at the speed of light, to communicate with robotic spacecraft. How long does it take a message to travel from Earth to a spacecraft at
a) Mars at its closest to Earth (about 56 million km)?
b) Mars at its farthest from Earth (about 400 million km)?
c) Pluto at its average distance from Earth (about 5.9 billion km)?

47) *Saturn vs. the Milky Way.* Photos of Saturn and photos of galaxies can look so similar that children often think the photos show similar objects. In reality, a galaxy is far larger than any planet. About how many times larger is the diameter of the Milky Way Galaxy than the diameter of Saturn's rings? (Data: Saturn's rings are about 270,000 km in diameter; the Milky Way is 100,000 light-years in diameter.)

48) *Galaxy Scale.* Consider the 1-to-10^{19} scale, on which the disk of the Milky Way Galaxy fits on a football field. On this scale, how far is it from the Sun to Alpha Centauri (real distance: 4.4 light-years)? How big is the Sun itself on this scale? Compare the Sun's size on this scale to the actual size of a typical atom (about 10^{-10} m in diameter).

49) *Universal Scale.* Suppose we wanted to make a scale model of the Local Group of galaxies in which the Milky Way Galaxy was the size of a marble (about 1 cm in diameter).
a) How far from the Milky Way Galaxy would the Andromeda Galaxy be on this scale?
b) How far would the Sun be from Alpha Centauri on this scale?
c) How far would it be from the Milky Way Galaxy to the most distant galaxies in the observable universe on this scale?

50) *Driving Trips.* Imagine that you could drive your car at a constant speed of 100 km/hr (62 mi/hr), even across oceans and in space. (In reality, the law of gravity would make driving through space at a constant speed all but impossible.) How long would it take to drive
a) around Earth's equator?
b) from the Sun to Earth?
c) from the Sun to Pluto?
d) to Alpha Centauri?

51) *Faster Trip.* Suppose you wanted to reach Alpha Centauri in 100 years.
a) How fast would you have to go, in km/hr?
b) How many times faster is the speed you found in part a than the speed of our fastest current spacecraft (around 50,000 km/hr)?

52) *Galactic Rotation Speed.* We are located about 27,000 light-years from the galactic center and we orbit the center about once every 230 million years. How fast are we traveling around the galaxy, in km/hr?

53) *Earth Rotation Speed.* Mathematical Insight 1.4 shows how to find Earth's equatorial rotation speed. To find the rotation speed at any other latitude, you need the following fact: The radial distance from Earth's axis at any latitude is equal to the equatorial radius times the *cosine* of the latitude. Use this fact to find the rotation speed at the following latitudes. (*Hint*: When using the cosine (cos) function, be sure your calculator is set to recognize angles in degree mode, not in radian or gradient mode.)
a)30°N
b) 60°N
c) your latitude

54) *Order of Magnitude Estimate.* Mathematical Insight 1.3 defines order of magnitude estimates, and in the text we estimated there are about 10^{22} stars in the observable universe by assuming that 100 billion large galaxies each have about 100 billion stars. Now, assume that there are also 1trillion small galaxies, but that each has only 10 million stars on average. How will this affect the estimate of the total number of stars in the observable universe? Explain your answer without calculating.