INSTRUCTOR'S MANUAL

21st Century Astronomy

SIXTH EDITION

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Contents

Preface

For each chapter of the textbook, you will find a corresponding chapter in the Instructor's Manual that contains all or most of the following sections:

INSTRUCTOR NOTES

- This section provides a brief overview of the chapter and a list of major topics discussed. It often includes common misconceptions to address and recommendations for additional resources.

DISCUSSION POINTS

- This section suggests important discussion topics and activities. The chapter Learning Goal associated with each item is noted.

PROCESS OF SCIENCE

- This section provides a brief overview of the chapter's Process of Science figure. We also have questions in Smartwork5 that relate to the figure.

ASTROTOUR ANIMATIONS

- The AstroTour animations are narrated, conceptual overviews with a consistent structure of Introduction—Explanation—Conclusion. This section of the Instructor's Manual briefly describes each AstroTour animation associated with the chapter and notes the corresponding section of the textbook.

ASTRONOMY IN ACTION VIDEOS

- The Astronomy in Action Videos are a series of mini-lectures and demos done by textbook author Stacy Palen. This section of the Instructor's Manual briefly describes each Astronomy in Action Video associated with the chapter and notes the corresponding section of the textbook as well as the length of the video.

INTERACTIVE SIMULATIONS

- Textbook author Stacy Palen has created seven Interactive Simulations that pair with selected Exploration activities. This section briefly describes each Interactive Simulation associated with the chapter and notes the corresponding section of the textbook.

TEACHING READING ASTRONOMY NEWS

- This section contains the worked solutions and discussion of the Reading Astronomy News questions.

CHECK YOUR UNDERSTANDING SOLUTIONS

- This section provides answers and supporting information for all of the in-chapter Check Your Understanding questions.

END-OF-CHAPTER SOLUTIONS

- This section provides worked solutions to all of the end-of-chapter questions and problems (Test Your Understanding, Thinking about the Concepts, and Applying the Concepts).

EXPLORATION

- This section briefly describes the Exploration activity and provides worked solutions to each question.

LEARNING ASTRONOMY BY DOING ASTRONOMY: COLLABORATIVE LECTURE ACTIVITIES

- This section introduces activities from the *Learning Astronomy by Doing Astronomy* workbook that are relevant to the chapter. The textbook reference of the associated topic is noted.

For adopters of *The Norton Starry Night Workbook*, the answers to the exercises are included at the end of the manual.

We hope that you will find the information in this manual useful. We welcome your comments, questions, and suggestions (contact your local Norton representative: http://books.wwnorton.com/books/find-your-rep/).

Finally, we would like to thank Ricardo Covarrubias of Milikin University and Jay Dunn of Georgia State University, Perimeter College, whose careful review improved the accuracy and usefulness of this manual.

Additional resources:

Norton Interactive Instructor's Guide (IIG)
iig.wwnorton.com/astro6

This new and searchable online resource is designed to help instructors prepare for lecture in real time. All of the content in this Instructor's Manual, and more, is located on the IIG. In addition to this manual's content, you will find: the Test Bank, AstroTour animations, Astronomy in Action videos, Interactive Simulations, Lecture PowerPoint slides, all of the textbook's art, photos, and tables, and Learning Management System Coursepacks (available in Blackboard, Canvas, Desire2Learn, and Moodle formats).

Smartwork5 Online Activities and Assessment
digital.wwnorton.com/astro6

More than 2,00 questions support *21st Century Astronomy, Sixth Edition*—all with answer-specific feedback, hints, and ebook links. Norton offers pre-made assignments for each chapter of the text to make it easy to get started, but Smartwork5 is also fully customizable.

Questions include ranking, labeling, and sorting exercises based on book and NASA art, selected end-of-chapter questions, versions of the Explorations (based on AstroTours and new Simulations), and questions that accompany the Reading Astronomy News feature in each textbook chapter. Astronomy in Action video questions focus on overcoming common misconceptions, while Process of Science guided inquiry assignments take students through the steps of a discovery and ask them to participate in the decision-making process that led to the discovery.

PART I:

Instructor's Manual

CHAPTER 1

Thinking Like an Astronomer

INSTRUCTOR NOTES

Chapter 1 is an introduction to the measures and methods of astronomy. Major topics include:

- our cosmic address; that is, the hierarchy of structures from the Solar System to the Laniakea Supercluster.
- relevant and relative distance scales, including the light-year, and relating those scales to an equivalent time.
- the scientific method and relevant vocabulary, with an emphasis on distinguishing a *theory* from an *idea.*
- mathematics as a way to recognize patterns, how to read both linear and logarithmic graphs, and unit conversion and scientific notation.

Students enroll for introductory astronomy courses for many reasons, but the most common one is to fulfill a general education requirement. We have found that in a large lecture hall (say 200 students or more) of a major university, the spread of educational backgrounds can be large. We teach students at every level, from incoming freshmen with no major declared to graduating seniors who have majored in a science, technology, engineering, and mathematics (STEM) field. For an open-enrollment, two- or four-year college, we have students who are earning college credit while still in high school, students who are also working full time, and some who are raising a family along with attending school. Returning students may not have had any exposure to basic math for a decade or more.

The goal of this first chapter is to ease all these students into their study of astronomy. It captures their interest by covering our cosmic address and translating huge distances into terrestrial time examples for a better grasp of large numbers. We may be quite comfortable discussing wavelengths in nanometers, particle densities in atoms per cubic centimeter, masses in 10^{30} kilograms, and distances in megaparsecs, but students are not. We find it useful to conduct exercises with Figures 1.1 and 1.3 or show a version of the "Powers of Ten" montages available online to provide students with some visual context for the ranges of size, mass, speed, and time that are discussed in this course.

Too often we hear the phrase "it's just a theory" as a way of dismissing facts that are personally unacceptable. Here the concepts of questioning, predicting, testing, disproving, and more about the scientific method are presented in a way that is relatable to everyday occurrences. Students are given practice with scientific notation and the graphing of data. The mathematics is presented as the language of, as well as a valuable tool for, science. Much of the quantitative problem solving in this course can be achieved through proportional reasoning, so in addition to asking questions about scientific notation and unit conversion, we can also introduce some basic ideas of how area or volume changes with size.

For many of our students, this is the last formal science course they will ever take. We have included learning outcomes that help them learn the process of science, gain scientific literacy, and understand the difference between science and pseudoscience. The seeds of these outcomes are sown in this first chapter, not only through discussion of the scientific method, but also through the various logical fallacies presented in the Exploration. Although science is ideally independent of culture or creed, it has often collided with religious or other strongly held beliefs. Therefore, because science is a human activity carried out by individuals who may hold nonscientific beliefs, we emphasize that we must construct safeguards within our work to counteract any personal bias that might taint the results. The emphasis is on how science is all about searching for objective truths that lead to conclusions that cannot be falsified, at least at this time.

DISCUSSION POINTS

- Have students look at the sketches shown in Figures 1.1 and 1.3. Ask them if they are familiar with any of the shapes and structures shown. Where have they encountered them before? (LG 1)
- Have students think about the times given in Figure 1.3. Discuss the distances and times between our planet and nearby stars, and relate that to the likelihood that we will communicate with extraterrestrials in our lifetime (remind students that we have only been broadcasting and listening for less than 100 years). (LG 1)

- Astronomers need to keep collecting data from the objects in the universe to find unexpected trends and to test hypotheses. Discuss how this process has analogies in students' own experiences. Have they ever had to collect data to learn something or to explore the unknown? Share in pairs and then with the class. (LG 2)
- Students could formulate a testable hypothesis about how the number of hours spent studying in a course will affect their grade in that course. Would the outcome depend on whether the course was in their chosen major? What other variables might affect the outcome of their efforts in a course? (LG 2)
- Ask students if they are familiar with any scientific equations. Discuss differences and similarities between a well-known scientific equation (for example, $F = ma$ or $E = mc^2$) and a world-renowned work of art. What processes went into creating each of these? How is each example used? (LG 3)
- How can we describe our astronomical origins? Start with the hydrogen atom minutes after the Big Bang and have students build a story of the "life" of that hydrogen atom from its beginning to its presence in their DNA. Set up a think-pair activity, and then randomly select a pair or pairs to share their stories. (LG 4)
- The chapter-opening image is the one taken of Earth by astronaut William (Bill) Anders in 1968 as part of the *Apollo 8* mission, as the orbiter came around the Moon and Earth appeared to "rise." What do students already know about the image? Do they think it was taken from a lander or an astronaut on the surface of the Moon? The question asked is, "Why is this considered one of the most famous photos ever taken?" The answer is that it was the first image taken of Earth from space by humans on a mission to another world. NASA put together a short 45th anniversary commemorative video that combined actual flight recordings, photo mosaics, and elevation data from the Lunar Reconnaissance Orbiter. The video is narrated by Andrew Chaikin, and sketches of the orbiter containing Anders, Jim Lovell, and Frank Borman are included for a more complete perspective of how the Earthrise picture was obtained. The video can be found at https://youtu.be/dE-vOscpiNc.

PROCESS OF SCIENCE

The Process of Science figure for this chapter introduces the basics of the scientific method. The emphasis is on how the process will repeat indefinitely as scientists continue to test the theory. Subsequent chapters in this text will emphasize actual examples of how the scientific method "works."

ASTROTOUR ANIMATIONS

None for this chapter.

ASTRONOMY IN ACTION VIDEOS

None for this chapter.

INTERACTIVE SIMULATIONS

None for this chapter.

TEACHING READING ASTRONOMY NEWS

1. Because light has a finite speed, it takes time for the light to get to us from distant galaxies. We assume that galaxies in the universe all formed at roughly the same time. For those galaxies that are the farthest away, light left them when they were very young, just forming. These galaxies will look the youngest to us. Galaxies that are closer will look older. Telescopes are like time machines.
2. If we are looking extremely far away, such as when the galaxies were only a few billion years old (a look-back time of around 12 billion years), and we see many more small galaxies than large galaxies, then that suggests that galaxies started small.
3. The observable universe is that part where light has had time to reach us. We cannot see the entire universe because there hasn't been enough time for light beyond there to reach us.
4. Since the question asks for learner statements, answers will vary.
5. Students are asked to do a search on galaxies. Answers will vary.

CHECK YOUR UNDERSTANDING SOLUTIONS

1.1 **(d)** radius of Earth **(a)** light-minute **(e)** distance from Earth to the Sun **(c)** light-hour **(f)** radius of the Solar System **(b)** light-year. Use Figure 1.3.

1.2 **(b)** Theories must be testable, and a theory is valid up until a test fails.

1.3 **(c)** Patterns and order are indicative of a physical process at play.

END-OF-CHAPTER QUESTIONS AND PROBLEMS SOLUTIONS

TEST YOUR UNDERSTANDING

1. **(f, e, c, b, a, h, g, d)** is the correct order from smallest to largest size.

2. **(a)** See Figure 1.3.
3. **(b)** We can connect facts through an underlying idea. Note that (a) one must accumulate facts to consider how they are related, and (c, d) that science makes predictions based on these relationships, but "understanding" is the development of these relationships.
4. **(a)** The universe is understood to be homogeneous and isotropic on its largest scales.
5. **(d)** The Sun is the center of our Solar System, just one of the billions of stars in our galaxy, and one of the billions of galaxies in the universe.
6. **(a)** It is the distance that light travels in one year.
7. **(c)** Occam's razor suggests that nature relies on the simplest (or most straightforward) processes.
8. **(d)** Distance units in terms of light speed are very convenient but sometimes odd to think about at first because we seem to be using *time* to refer to distance. This problem shows us two ways of considering the meaning of light distance.
9. **(d)** A reading of Figure 1.7b indicates that the answer cannot be obtained from a linear plot. A reading of the log-linear plot in Figure 1.7c, however, shows that at time step 4, the number of viruses is more than 10 times what it was at the start.
10. **(d)** As the answer indicates, science relates only to the natural world.
11. **(c)** Our understanding must be tested, and at any time, a test could show that it is wrong. Note that this is not an issue of being worthless or incomplete, but merely reflects the fact that we are constantly testing our theories and hypotheses.
12. **(c)** Light travels a light-year in one year, so a star that is 10 light-years away emitted its light 10 years ago for us to see it today.
13. **(d)** Carbon is made inside stars.
14. **(b)** Except for hydrogen and helium (and a tiny bit of lithium), all of the elements found on Earth were produced in stars. Note that the beryllium produced in the Big Bang was unstable and decayed long before Earth formed.
15. **(b, d, a, c, e)** The material for the Sun had to come before the Sun could be formed. Gas came first (b), the gas formed stars to make heavier elements (d), the stars blew up to spread those elements around (a), and then the gas had to collect (c) before it could form the Sun and the planets (e).

THINKING ABOUT THE CONCEPTS

16. Tau Ceti e, Tau Ceti, Milky Way Galaxy, Local Group, Virgo Supercluster, Laniakea Supercluster, universe
17. The cosmological principle essentially states that observers in the universe should find that the natural laws governing their local region are representative of the natural laws governing the universe as a whole. Consequently, they should derive the same natural laws that an observer on Earth derives.
18. 8.3 minutes (see Figure 1.3).
19. Andromeda is about 2.5 million light-years away (see Figure 1.3), so it would take 2.5 million years for the light from the exploding star to reach Earth.
20. Answers will vary. An example is general relativity superseding Newtonian mechanics, which began at the first step of the Process of Science for this chapter when Einstein reinvisioned gravity and spacetime. Another example occurred in the 1920s when it was predicted that the Andromeda galaxy was just in a distant part of the Milky Way, perhaps 300,000 light years distant. Edwin Hubble employed the "observe" step and found that the result did not support the hypothesis: the Andromeda galaxy was, in fact, millions of light years away.
21. This does not qualify as a scientific theory because it is not falsifiable. Although it is possible that we may someday stumble upon irrefutable evidence that aliens visited Earth in the remote past, the absence of evidence today cannot be used to refute the hypothesis. In fact, proponents of the theory will simply argue that we just have not found any evidence yet. Evidence that could support the theory would include finding advanced technology in ancient archaeological sites or buried in old geological layers. The only tests we can think of to refute the hypothesis are either to demonstrate that every piece of technology and archaeological monument could have been reasonably constructed with human knowledge of the time or else invent a time machine and return to the most likely times for aliens to have visited Earth. Because option 2 is utterly implausible and option 1 does not preclude alien visitations, it is impossible to falsify the hypothesis.
22. *Falsifiable* means that something can be tested and shown to be false or incorrect through an experiment or observation. Some examples of ideas that cannot be falsified are religious beliefs, political views, emotional statements, and opinions. Students may have a wide variety of these and other ideas, but all sacred cows are usually considered to be not falsifiable by the people holding those beliefs. Falsifiable ideas include cause and effect and logic.
23. A *theory* is generally understood to mean an idea, regardless of any proof, evidence, or way to test it. A *scientific theory* is an explanation for an occurrence in nature that must be based on observations and data and make testable predictions.

24. A *hypothesis* is an idea that might explain some physical occurrence. A scientific *theory* is a hypothesis that has been rigorously tested.
25. (a) Yes, this is falsifiable. (b) Find a sample of a few hundred children born during different moon phases, who come from similar backgrounds and go to similar schools and follow their progress for a number of years.
26. In 1945, our distance-measuring methods were not correctly calibrated and, as a result, our calculation of the distance to Andromeda was wrong. As we improved that calibration, we found different and more reliable measurements of its distance. In science, statements of "fact" reflect our current best understanding of the natural universe. A scientific "fact" does not imply that science has determined absolute truth; rather, it is simply a statement that this is the best understanding of nature that our current knowledge and technology supports. Over time, all scientific "facts" evolve as our knowledge base and technology grow.
27. Answers will vary. Depending on the generality of the horoscopes, students may provide a wide array of answers for this question. For general statements, students might find that several, if not all, of the horoscopes on a given day could describe their experience. For a very specific horoscope, we expect that it should match approximately 1/12th of the students, regardless of their astrological sign. In any event, if astrology accurately reflected some natural truth, we would expect nearly everyone to find one and only one horoscope each day that describes his or her experience, that the horoscope would match the person's astrological sign, and that the daily horoscope would be accurate for each person for the entire week of record keeping. Students should perform this experiment and be honest with themselves about the results. Students need to be aware of any bias by those who have prior beliefs in horoscopes and who will likely not provide objective data.
28. Taken at face value, this is a ridiculous statement, but there are several items to consider critically before we apply a label of "not reputable." First, was this statement a sound bite taken out of context? Did the scientist simply misspeak when he or she might have been trying to say that we have not yet found extraterrestrial life? If, in fact, the statement can be taken at face value, then the credibility of the scientist might be called into question because he or she has forgotten that absolute truth is not falsifiable (and therefore not scientific) by definition.
29. Some scientific fields rely heavily on math, but not all. Following the scientific method is the important part, not use of mathematics.
30. Only hydrogen and helium (with perhaps a trace amount of lithium) were created in the Big Bang. Heavier elements such as carbon, oxygen, nitrogen, sodium, silicon, iron, and more are manufactured in the interiors of massive stars. At least one generation (and more likely several generations) of stars must die in massive supernova explosions to make heavy elements available to construct planets and serve as the building blocks for life. Therefore, because all the heavy elements in our bodies were originally manufactured in stars, it is fair to claim that we are truly made of stardust.

APPLYING THE CONCEPTS

31. **Setup:** To convert to scientific notation, remember that when the number is greater than one count all digits to the right of the first non-zero digit, and when the number is less than one count the number of digits between the decimal point and first non-zero digit.
Solve: (a) 7×10^9 (b) 3.46×10^{-3} (c) 1.238×10^3
Review: A good way to check is to use a scientific calculator, where "times 10 to the" is usually the "EE" key.
32. **Setup:** To convert scientific to standard notation, move the decimal point the number of digits indicated in the exponent, to the right if the number is positive, and left if negative.
Solve: (a) 534,000,000 (b) 4,100 (c) 0.0000624
Review: Again, you can test this by using your calculator.
33. **Setup:** Distance is given in terms of speed and time by $d = vt$, where v is speed and t is time. If speed is in km/h, then use time in hours, for which we may have to convert. Remember that there are 60 minutes in an hour.
Solve: (a) $d = vt = 35\,\frac{\text{km}}{\text{h}} \times 1\text{h} = 35\,\text{km}$
(b) $d = vt = 35\,\frac{\text{km}}{\text{h}} \times \frac{1}{2}\text{h} = 17.5\,\text{km}$
(c) $d = vt = 35\,\frac{\text{km}}{\text{h}} \times \frac{1}{60}\text{h} = 0.58\,\text{km}$
Review: A good sanity check is to make sure the distance traveled becomes smaller if the time traveled decreases.
34. **Setup:** We are given the relationship that surface area, A, is proportional to radius, r, squared, or $A \propto r^2$. To work a proportional-reasoning problem, insert the factor by which one variable changes into the formula to see how the result changes.
Solve: (a) If r doubles, then $r \rightarrow 2r$, or r changes by a factor of 2. Putting this in our formula shows $A \propto 2^2 = 4$, or that the area changes by a factor of 4. (b) If r triples, then it changes by a factor of 3, or $A \propto 3^2 = 9$.

(c) If r is halved, then $r \to \frac{1}{2}r$, or r changes by a factor of $\frac{1}{2}$; therefore, $A \propto \left(\frac{1}{2}\right)^2 = \frac{1}{4}$. (d) If r is divided by 3, then $r \to \frac{1}{3}r$ and $A \propto \left(\frac{1}{3}\right)^2 = \frac{1}{9}$.

Review: Note first that the change in area is much larger than the change in radius, which reflects the dependence on radius squared. Note also how easy it is to do proportional reasoning rather than using the full surface-area formula ($A = 4\pi r^2$), when all we need to know is how much the result changes.

35. **Setup:** In this problem, we convert among distance, rate, and time with $d = vt$, or solving for time, $t = d/v$. The problem is straightforward because the units of distance are already the same.

Solve: $t = \frac{d}{v} = \frac{384{,}000 \text{ km}}{800 \text{ km/h}} = 480 \text{ h}$. There are 24 hours in a day, so this would take $480 \text{ h} \times \frac{1 \text{ day}}{24 \text{ h}} = 20 \text{ days}$, or about two-thirds of a month (assuming the typical month is 30 days).

Review: A typical flight from New York to London takes about 7 hours and covers a distance of about 5,600 km. The moon is about 69 times farther away, so it would take about $69 \times 7 \text{ h} = 483$ hours to reach the Moon using these estimates. This is basically the same amount of time as we found by exactly solving the problem.

36. **Setup:** In this problem, we will convert between distance, rate, and time with $d = vt$ or, solving for speed, $v = d/t$. The problem is straightforward because the units of distance are already the same.

Solve: $v = \frac{d}{t} = \frac{384{,}000 \text{ km}}{3 \text{ days}} \times \frac{1 \text{ day}}{24 \text{ h}} = 5{,}333 \text{ km/h}$.

This is about $\frac{5{,}333 \text{ km/h}}{800 \text{ km/h}} = 6.7$ times faster than a jet plane.

Review: Using the result from problem 35, we have to travel $\frac{20 \text{ days}}{3 \text{ days}} = 6.7$ times faster than a jet plane, which agrees with our solution.

37. **Setup:** We are given the problem in relative units, so we don't need to use our speed equation or use the actual speed of light. Instead, we will use ratios.

Solve: (a) If light takes 8.3 minutes to reach Earth, then it takes $8.3 \text{ min} \times 2 = 16.6$ minutes to go twice as far. Neptune is 30 times farther from than the Sun than Earth is. When Neptune and the Earth are on the same side of the Sun (Neptune is in opposition), Neptune is 29 AUs from Earth. This means that light will take $8.3 \text{ min/AU} \times 29 \text{ AU} = 240.7$ minutes, or $240.7/60 = 4.0$ hours.

(b) This means that sharing just one sentence will take about 8 hours, so it could take a few days just to say hello, talk about the weather, and think of something else to say. This is the shortest possible time happening when Neptune is at its closest approach to Earth.

Review: If you watch *2001: A Space Odyssey*, you will note that the televised interview between Earth and David Bowman had to be conducted over many hours and then edited for time delays. This was factually correct. Because Neptune is about six times farther away than Jupiter, it stands to reason that it would take light and communication a lot longer still.

38. **Setup:** Light travels at approximately 3×10^5 km/s. To find the travel time, use $d = vt$ or $t = \frac{d}{v}$.

Solve: $t = \frac{d}{v} = \frac{5.6 \times 10^7 \text{ km}}{3 \times 10^5 \text{ km/s}} = 187 \text{ s}$

Likewise, using $t = \frac{d}{v} = \frac{4 \times 10^8 \text{ km}}{3 \times 10^5 \text{ km/s}} = 1330 \text{ s}$.

Review: Light takes about 8.3 min to travel from the Sun to Earth, or about 498 s. If, as an estimate, Mars's distance from Earth ranges from 0.52 AU to 2.52 AU, then the light travel time will range from 260 s to 1255 s. Given the eccentricity of the orbit of Mars, our numbers are consistent with these approximations.

39. **Setup:** We are given the relationship surface area $A \propto r^2$. To work a proportional-reasoning problem, insert the factor by which one variable changes into the formula to see how the result changes.

Solve: The Moon's radius is about one-fourth that of the surface of Earth; therefore, its surface area is $A \propto \left(\frac{1}{4}\right)^2 = \frac{1}{16}$ the area of Earth's surface.

Review: We saw this same behavior in problem 34.

40. **Setup:** We will use the equation $d = vt$, where the distance is 3.6×10^4 km, one way, and light travels at $v = c = 3 \times 10^5$ km/s.

Solve: $t = \frac{d}{c} = \frac{2 \times (3.6 \times 10^4 \text{ km})}{3 \times 10^5 \text{ km/s}} = 0.24$ s, or about $\frac{1}{4}$ of a second

Review: If we are receiving information by an Internet satellite on a regular basis, we almost never notice a lag so the time has to be short, on the order of what we found (much less than 1 second).

41. **Setup**: Let the horizontal axis be time and vertical be population. If we choose to plot a graph in linear space, then a constant population will be a horizon-

tal line followed by a sharp, curved increase in the population, resembling Figure 1.7b. An exponential growth will look similar to the log-linear graph of Figure 1.7c. After a 50-year time step, an almost vertical line down will represent a crash, back down to the original population number. Two of these would be represented by a ramp up to a 50-year time followed by a vertical line down, whether a linear or long-linear graph is used.

Solve: Answers will vary. The question gives an example in which the baseline population is 1 unit.

Review: Note the growth starts out very slowly, jumps up very rapidly, and takes a nosedive down.

42. **Setup:** We need our assumptions of speed. A car goes 60 miles per hour, on average, if we include filling up with gas, eating, and restroom breaks. We also need to relate distance, rate, and time with the formula distance equals rate times time, or $d = vt$.

Solve: Solving for time, $t = d/v$, so by car, $t = 2{,}444$ miles/60 mph = 41 "car" hours. Because there are 24 hours in a day, the car takes 41/24 = 1.7 "car" days. Note these assume you travel around the clock, which we do not usually do unless working with a team.

Review: If you drive "almost" nonstop, you can go from NY to LA in 3 days. This is consistent with our value, because that assumed no stops at all.

43. **Setup:** For water to freeze, it has to cool down to 0°C; then the liquid has to become solid.

Solve: (a) This theory makes no sense to us because hot water will have to cool down to the starting temperature of the cold water before it starts to freeze. That takes time that was not needed by the water that started out cold.

(b) Yes, this is easily testable. Simply try it in a freezer.

(c) We tried it, and it took about five times longer for the hot water to freeze, confirming our hypothesis.

Review: Going back to our original physical reasoning, we see that this theory could be easily refuted without experimentation. Sometimes refuting a theory is not as straightforward, however, and experiments must be performed.

44. **Setup:** On the surface, it seems that the two pizzas cost the same number of dollars per inch; but remember that each pizza is a thin cylinder, so we eat the volume, not the diameter.

Solve: If both pizzas have the same thickness, then we only need to worry about area, $A = \pi r^2$. Since the area goes as radius squared, the area of the 18-inch pizza is four times larger than the area of the 9-inch one. Since the 18-inch pizza costs only twice as much, it is more economical to buy the larger pizza.

Review: Often, larger items cost less per unit than smaller ones because almost the same amount of labor went into making them, and labor is generally the highest part of the cost. This is why you should always check the unit price when buying things.

45. **Setup:** For part (a), use the formula given, $= 2\pi r$. For part (b), we need to relate distance, speed, and time by $d = vt$, where we will solve for time. We use the formula again for part (c), where we must remember there are 24 hours in one day.

Solve: (a) $C = 2\pi r = 2\pi \times (1.5 \times 10^8\ \text{km}) = 9.4 \times 10^8\ \text{km}$

(b) $$v = \frac{d}{t} = \frac{9.4 \times 10^8\ \text{km}}{8{,}766\ \text{h}} \approx 1.075 \times 10^5\ \text{km/h}, \quad \text{or}$$

about 107,500 km/h

(c) Because $d = vt$, and because there are 24 hours in one day, Earth moves about 2,580,000 km per day.

Review: It is amazing that we are hurtling around the Sun at more than 100,000 km/h and do not even realize it. Why? It's because everything else (planets, the Sun, other stars) is so far away that we have no reference point to enable us to observe this breakneck speed.

USING THE WEB

46. Europa, Eris, Pluto, and Triton are about the size of the United States. Venus is about the size of Earth. Lots of stars are larger than an astronomical unit, but Rigel, Gacrux, and Alnitak are about that size. *Voyager 1* is 17 billion km, 0.002 light-years, or 0.73 light-days away. The Stingray and Cat's Eye Nebulae and Gomez's Hamburger are about the same size as the distance from the Sun to nearest star. The Milky Way is 120,000 ly / 2 ly = 60,000 times larger than the Solar System, which includes the Oort Cloud. The Local Group is 10 million ly across while the Milky Way is 120,000 ly in diameter, a ratio of ~80. The observable universe is 93 billion ly across; ratio of the universe to the Local Group is 9,300.

47.(a) Radio broadcast programs have traveled 70 ly. The Sun is not particularly luminous once we get beyond the nearby red dwarf stars. Answers will vary about the video's effectiveness.

(b) Answers will vary concerning the "Powers of 10" circles in explaining the size and scale of the universe.

48. Students go to the Astronomy Picture of the Day and choose an archived picture or video to describe. Answers will vary.

49. Involves investigating news articles about astronomy or space. Answers will vary.

50. Involves going to a blog about astronomy or space. Answers will vary.

EXPLORATION

This exploration asks students to consider the logic behind a variety of statements, many of which they had not considered before. Besides the examples given in the exploration, ask students to come up with one of their own examples that can be classified as one of the logical fallacies included here.

EXPLORATION SOLUTIONS

1. This is an example of *post hoc ergo propter hoc*, in which we assume that the chain mail caused the car accident.
2. This is a slippery slope, because we are assuming that our performance on the first event must influence the next.
3. This is a biased sample, or the use of small-number statistics, because we assume that our small circle of friends represents everyone.
4. This is an appeal to belief, where we argue that because most people believe it, it must be true.
5. By attacking the professor rather than the theory, we are committing an *ad hominem* fallacy.
6. This is an example of begging the question (a bit of a syllogism, too) in which the proof of the assertion comes from another person's assertions.

LEARNING ASTRONOMY BY DOING ASTRONOMY: COLLABORATIVE LECTURE ACTIVITIES

The *Learning Astronomy by Doing Astronomy* workbook activities that are relevant to Chapter 1 are introduced here. For more information, please see the *Learning Astronomy by Doing Astronomy* workbook, the *Instructor's Manual* for the workbook, and the PowerPoint clicker question slides associated with the workbook. Our goal is to have complete coverage across all topics in an introductory astronomy course.

ACTIVITY 1: MATHEMATICAL AND SCIENTIFIC METHODS

This activity reviews the mathematics that students may encounter in this course. This activity helps with tools such as working with logarithms, the small-angle formula, scientific notation, or scaling exercises, like those used to find the scale of a map; laboratory techniques concerning measurements; the uncertainties in those measurements; and statistical analysis. In the first six sections, students review specific mathematical topics and laboratory techniques. These sections include explanations and practice problems. In the last section, students pull multiple concepts together to analyze images of three galaxies. Activity 1 covers the majority of math concepts presented in the workbook. Each individual activity has a set of preactivity questions that tutor students on the math that is included. Specifically, students will:

- demonstrate knowledge of the essentials of mathematics through practice and review of:
- scientific notation and powers of 10;
- algebra;
- logarithms;
- the small-angle formula;
- the use of scale factors and scaling;
- statistics and uncertainties in measurements.
- describe the process of science and the scientific approach as personally experienced.

ACTIVITY 2: ASTRONOMICAL MEASUREMENTS: EXAMPLES FROM ASTRONOMICAL RESEARCH

In this activity students explore the relationship among apparent brightness, luminosity, and distance and learn to manipulate more advanced equations used in astronomy. Specifically, students will:

- apply the small-angle formula.
- distinguish between apparent magnitude and absolute magnitude and relate them correctly to the concepts of apparent brightness and luminosity.
- relate the ratio of distances to the brightness ratio for stars of equal luminosity.
- solve for the distance to a star using the parallax angle.
- find absolute magnitude from apparent magnitude and distance.
- demonstrate proficiency in manipulating more advanced equations used in astronomical research.