INSTRUCTOR'S MANUAL

At Play in the Cosmos

SECOND EDITION

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SECOND EDITION

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Preface

For each chapter of the textbook, you will find a corresponding chapter in the *Instructor's Manual* containing all or most of the sections listed below. Where applicable in the manual, the chapter Learning Goal associated with an item is noted.

INSTRUCTOR NOTES

- This section provides an overview of the chapter and a list of major topics discussed. The end of the Instructor Notes section lists each Going Further box and scientist interview within the chapter for quick reference. Also included are ideas for teaching with the scientist interviews.

DISCUSSION POINTS

- This section suggests important discussion topics and activities.

ANATOMY OF A DISCOVERY

- The Anatomy of a Discovery figures illustrate the people and processes involved in making important discoveries. This section describes each chapter's figure and suggests ideas for teaching with it.

INTERACTIVE SIMULATIONS

- The Interactive Simulations enable students to play with physical relationships that are key to the study of astronomy. This section describes each Interactive Simulation associated with the chapter and what students are expected to learn.

CHECKPOINT SOLUTIONS

- This section provides solutions to all of the in-chapter Checkpoint questions.

END-OF-CHAPTER SOLUTIONS

- This section provides solutions to all of the end-of-chapter questions and problems (Narrow It Down: Multiple-Choice Questions, To the Point: Qualitative and Discussion Questions, and Going Further: Quantitative Questions).

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 and what students are expected to learn.

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.

Finally, we would like to thank Deepshikha Shukla of Rockford University and Ewa Burchard of Los Angeles Southwest College, whose careful review improved the accuracy and usefulness of this manual.

Additional resources:

NORTON INTERACTIVE INSTRUCTOR'S GUIDE (IIG)

iig.wwnorton.com/cosmos2

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, the Lecture Slides, all of the textbook's art and tables, and the Interactive Simulations. Each resource is tagged by topic and chapter.

SMARTWORK5 ONLINE ACTIVITIES AND ASSESSMENT

digital.wwnorton.com/cosmos2

Smartwork5 is Norton's online tutorial and homework system. Over 900 Smartwork5 questions support the Second Edition of *Astronomy: At Play in the Cosmos*—all with answer-specific feedback, hints, and ebook links. Questions include ranking and sorting tasks, selected end-of-chapter problems (both multiple-choice and algorithmic numeric entry), labeling exercises based on book art, guided inquiry activities based on the Interactive Simulations, and new postmission questions based on *At Play in the Cosmos:* The Videogame.

In addition, guided-inquiry "Process of Science" assignments help students apply the scientific method to important questions in astronomy, challenging them to think like scientists.

Smartwork5 offers template assignments but is also fully customizable. You can quickly find questions by filtering for specific learning objectives or problem type/series. You can also modify any system question or even create your own.

Smartwork5 provides rich diagnostic data on student performance, and it can integrate with campus Learning Management Systems (LMS).

TEST BANK

The Test Bank assesses a common set of learning objectives, consistent with Smartwork5 online homework, and provides over 1,200 multiple-choice and short-answer questions. Questions are classified according to Bloom's taxonomy (remembering, understanding, applying, analyzing, and evaluating), difficulty level, and section. The Test Bank makes it easy to construct meaningful and diagnostic exams.

POWERPOINT LECTURE SLIDES

These ready-to-use lecture slides complement the text by providing summaries of central topics, integrated photographs and art, class questions (including questions that address common misconceptions), and links to the Interactive Simulations. These lecture slides are editable and are available in Microsoft PowerPoint format. Norton also provides an update service—lecture slide presentations on engaging new topics—that enables instructors to cover new developments in astronomy soon after they occur.

LEARNING ASTRONOMY BY DOING ASTRONOMY WORKBOOK: COLLABORATIVE LECTURE ACTIVITIES, SECOND EDITION

Students learn best by doing. Devising, writing, testing, and revising suitable in-class activities that use real astronomical data, illuminate astronomical concepts, and ask probing questions that encourage students to confront misconceptions can be challenging and time-consuming. In this workbook, the authors draw on their experience teaching thousands of students in many different types of courses (large in-class, small in-class, hybrid, online, flipped, and so on) to present 36 field-tested activities that can be used in any classroom today. The activities have been designed to require no special software, materials, or equipment, and to take no more than 50 minutes to complete. Pre- and post-activity questions are now available in Smartwork5 so instructors can easily assess student understanding before and after each activity.

Instructor's materials, including PowerPoint versions of the pre- and post-activity class questions, are available at Norton's Instructor's Site.

STARRY NIGHT PLANETARIUM SOFTWARE (COLLEGE VERSION) AND NORTON STARRY NIGHT WORKBOOK

Starry Night is a realistic, user-friendly planetarium simulation program designed to enable students in urban areas to perform observational activities on a computer screen. Norton's unique accompanying workbook offers observation assignments that guide students' virtual explorations and help them apply what they've learned from reading assignments in the text.

AT PLAY IN THE COSMOS: THE VIDEOGAME

Backed by academic research on how students learn through play, we've developed and updated the videogame At Play in the Cosmos with the Gear Learning studio at the University of Wisconsin and the Learning Games Network, with authorial guidance from Adam Frank and Jeff Bary. The game challenges students to apply what they've learned and to learn more, by flying challenging missions and confronting problems in astronomy—such as finding habitable exoplanets. The game offers 22 missions, each one tied to specific learning objectives, plus an Exploration Mode in which students can visit and obtain data from any of the astrophysical objects in the game. Each mission asks students to apply the right tool to the job.

Instructors can have students play the game before or after class, in the classroom or the lab. Students can also play whenever they want outside of class. The videogame reports student diagnostic data to a grade book, enabling instructors to assess students' engagement and progress. Smartwork5 now supports the videogame by providing instructors with questions and problems that will assess students' understanding of concepts after they have completed different missions.

We have seen instructors use the game in a variety of ways:

- using selected missions as labs
- having students play together in class and discuss
- using the game for in-class, instructor-led demos, with participation from students
- awarding credit (required or extra) for completing a target number of missions

In a number of cases, *instructors waited until the fourth or fifth week of class to introduce the game.* That way, intro students, many of whom are in their first semester of college, feel more grounded in the course, the subject matter, and their college/university setting before using this new learning tool. On the other hand, introducing students to the game during class time just to show them what they have at their disposal has proven engaging. (Note that the first mission, as covered in detail below, references the concept of basic spectroscopy, which most instructors won't teach on the first day of class).

An Instructor's Manual specifically for the game is available on the game's instructor resourse page. It provides more support for meaningfully incorporating the game into your course. It includes both discussion/essay-style questions and multiple-choice questions that can be used for homework, in-class discussion, or on exams.

We believe that students will get the most out of the game when it is incorporated into your syllabus. Students have busy lives and tend to put off or forget about "optional" resources.

If you have any suggestions for how to better incorporate *At Play in the Cosmos: The Videogame* into your course, please don't hesitate to reach out!

PART I

Instructor's Manual

CHAPTER 1

Getting Started: Science, Astronomy, and Being Human

INSTRUCTOR NOTES

Chapter 1 is an introduction to the history and human context of astronomical science. Major topics include:

- Tracing the history of human beings' knowledge of astronomical phenomena and how it is applied across cultures and eras. (LG 1.1)
- Examining size and distance scales, time scales, and the use of scientific notation in astronomy. (LG 1.2)
- Presenting the major categories of structure in the Universe. (LG 1.3)
- Explaining how the scientific method increases our understanding about the Universe and how it differs from pseudoscience. (LG 1.4)
- Explaining the importance of scientific literacy for making informed decisions in our high-tech society. (LG 1.5)

This course is generally taken by nonscience majors to fulfill a general science requirement. You may want to have students fill out a questionnaire on the first day of class to get a quick synopsis of their science and math backgrounds, as well as to help students start to get to know one another. Even if the questionnaire reveals a high overall skill level, some students may still doubt their math and/or science abilities. This discomfort may stem from experiences in previous classes. There may also be preconceived notions about the class being boring, or that the emphasis will be on math and physics rather than on astronomy. Do your best to ease their fears by taking the time to identify and address the issues that concern them. A good icebreaker and concerted efforts to capitalize on their innate curiosity and interests can do wonders to encourage participation and open them up to wanting to learn more.

Astronomy operates on a vast range of size and time scales, from subatomic to large-scale structures, and from nanoseconds to billions of years. Section 1.2 takes a comparative look at some of these scales through the lens of scientific notation. The review of scientific notation in Going Further 1.1 presents a comprehensive overview of the basic operations students need to be able to perform. Most of the quantitative problem solving required by this textbook can be accomplished through proportional reasoning, such as figuring out how many times larger Jupiter is than Earth. In addition to covering scientific notation and unit conversion, it can be helpful to discuss related concepts, such as how both area and volume change with radius.

Depending on your school's curriculum, this may be the last formal science course your students will take. Science can be fun; try to impart that sensibility before they leave. It's not all chalk and talk. Science should be an experience of active engagement. This textbook has been designed to achieve that very goal. Some of the learning outcomes will be to vet the scientific literacy of a source, learn how science is done, and know the difference between science and pseudoscience. The seeds of curiosity are sown in this first chapter as the student learns that humans have been investigating the heavens since prehistoric times, these endeavors being enshrined in the many archeoastronomical monoliths found scattered across the globe. These relics preserve for us snapshots of humanity's long history of wonder and investigation. Astronomy is widely regarded as the oldest of the sciences; the recognition of patterns in the night sky was of known benefit to the earliest civilizations. They monitored the regular cycles of the Sun, Moon, and stars in an effort to better understand their place among them. Emphasizing this ongoing questioning of nature throughout the history of humanity can help students recognize their own interests as a part of this ancient trend.

Going Further boxes included in this chapter:

- Going Further 1.1 Working with Scientific Notation

Scientist interviews included in this chapter:

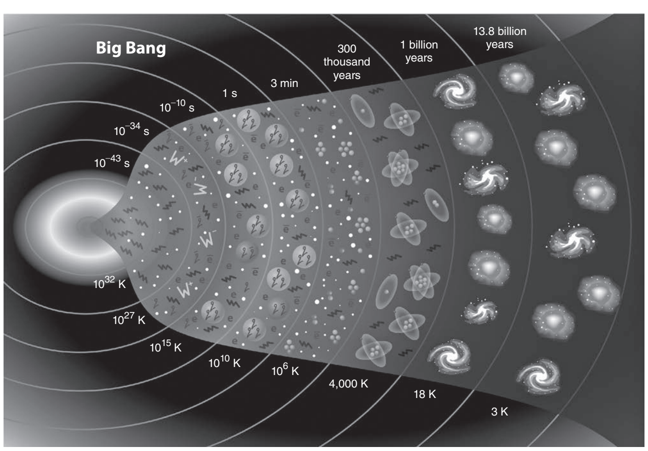
- Lucianne Walkowicz

TEACHING IDEAS:

- Ask students for examples of scientific discoveries that followed processes that were not as straightforward and clear cut as might be implied by a simplistic view of the scientific method.
- See if students can identify examples of scientific investigations during which the question being asked evolved appreciably in form or changed completely.

DISCUSSION POINTS

- Have students look at the 5,000-year-old monument in Figure 1.1. Ask them if they have seen similar shapes or structures in other parts of the country or world. (LG 1.1)
- Ask students when the Newgrange astronomical event (Figure 1.1) occurs and why this time of year was likely chosen. Discuss how the alignment of the structure relates to the seasons of the yearly calendar. (LG 1.1)
- The night sky is our window into time and space. Modern astronomy is the result of many thousands of years of observations and the genius of many individuals and cultures. Just as astronomers continue to collect data from this vast universe and find both expected and unexpected trends, it is important for students to recognize the trends that exist in their own lives. A simple exercise that students can do to gauge their actual versus desired outcome is to track the amount of time spent studying and asking questions during a professor's office hours in order to gain a more realistic perspective on their course progress and performance. (LG 1.1)
- Work together with students to formulate Earth's "cosmic address," starting with our position in the Virgo supercluster and ending with our location in the Solar System. (LG 1.2)
- Introduce, at a high level, IM Figure 1.1, both as a way of getting students to think in terms of cosmic timescales and as a temporal roadmap of the course. (LG 1.2)
- Demonstrate how to add, subtract, multiply, and divide numbers written in scientific notation, asking students how to proceed at key points in the calculations. (LG 1.2)



IM Figure 1.1 (Figure 1.14) Cosmic History Since the Big Bang

- Starting with a list of several categories or structures of astronomical interest having sizes smaller than that of a person, have students arrange them in order of increasing size. Also see if they can give some reasons as to why these objects are of relevance to the course. Do the same with a list of large astrophysical objects. (LG 1.3)
- Discuss the roots of scientific thinking as manifested by early sky watchers, navigators, farmers, and others who sought to understand (and potentially exploit) various patterns encountered in the natural world. (LG 1.4)
- Ask students if they are familiar with the scientific method. If so, have them explain it and discuss what options are available if an experiment fails. Is astrology a science or a pseudoscience? Why or why not? (LG 1.4)
- Discuss climate change and the depletion of natural resources. Ask students whether the threat of nuclear weapons and biological warfare pose any major challenges. If so, what are they? Poll students to see what other issues involving science and technology they see as offering either great promise or great threat. (LG 1.5)
- Discuss with your students how both science and technology dominate every facet of our lives. Ask them if an interest in different fields seem contradictory, such as a mix of science, art, and religion. Discuss the benefits and challenges of science and technology. (LG 1.5)

ANATOMY OF A DISCOVERY

How far away is the Sun? (LG 1.2)

The discussion outlines the major steps culminating in the first accurate estimates of Earth–Sun distance. Advancing beyond the relative distance information for planets in our Solar System achieved in the 17th century, the new technique, proposed by Edmund Halley, involved the analysis of observational data from transits of Venus across the face of the Sun when viewed from two distinct latitudes on Earth.

TEACHING IDEAS:

- Ask students how astronomers might have gone about observing the transit of a planet, at a time before solar filters existed, without putting their eyesight at risk.
- Have students explain why it is necessary for a transit to be viewed from two different latitudes for this technique to work. Would observations from two different longitudes work? Why or why not?

INTERACTIVE SIMULATIONS

Easy-to-use interactive simulations allow students to play with physical phenomena. This Instructor's Manual provides learning goals outlining ways in which students can use each simulation to further his or her understanding of each topic.

SCALE OF THE UNIVERSE (LG 1.2)

- Students will be introduced to astronomical distance and size scales as well as to relative size comparisons of the most common astronomical objects and structures.
- Students will be introduced to many common classes of objects in the Universe, e.g., nebulas, planetary systems, planets, stars, star clusters, forming stars, exploding stars, galaxies, galaxy clusters, etc.
- Students will familiarize themselves with the "meter sticks" astronomers use to measure distances, e.g., astronomical unit and light-year.

CHECKPOINT SOLUTIONS

1.1. Answers may vary. (a) An example of an ancient astronomical observation is that of Giovanni Schiaparelli who, studying Mars through a low-resolution telescope in 1877, painstakingly sketched what he perceived as canals on the Martian surface. An updated example of this early set of observations is provided by the Martian rovers currently scouring the surface of the planet. (b) The comparison between ancient and modern observations highlights humanity's unending quest for greater understanding of the world around us, illustrates the ongoing evolution of prevailing scientific descriptions of the natural world, and emphasizes the role played by technological advances in making new discoveries possible.
1.2. Answers may vary. (a) A power of ten refers to how many times a number is to be multiplied (or divided) by the number 10 as denoted by the positive (or negative) integer exponent of a quantity when written in scientific notation. (b) To divide two numbers in scientific notation you (1) divide the coefficient of the numerator by that of the denominator to get the new coefficient, and (2) subtract the exponent of the denominator from that of the numerator to get the new exponent.
1.3. Answers may vary. Using our Sun ($L \approx 10^9$ meters) and the Milky Way ($L \approx 10^{21}$ meters) for the comparison, a galaxy is roughly $21 - 9 = 12$ orders of magnitude larger than a star.
1.4. Answers may vary. (a) Taller candidates in presidential elections have tended to be the winners, which may be evidence that people have bias for taller leaders. Some claim cell phones are linked with brain cancer, but there is no evidence for that association. (b) The insistence of science on testable hypotheses and its reliance on disconfirming instances to signal fundamental problems with a given model insulate it to a high degree from many such cognitive biases.
1.5. Answers may vary. (a) Ever-increasing computational power and the progressive decrease in data storage costs has given rise to the collection and mining of big data, accompanied by a host of novel threats to personal privacy. (b) The night sky was closely studied by early priestly classes since the ability to predict astronomical phenomena such as eclipses lent an air of legitimacy to and considerably enhanced the power of such offices. By contrast, the ability of today's space-based sensor technology to probe physical phenomena at unprecedented levels of accuracy has led to the emergence of an entirely new subfield—precision astronomy.

END-OF-CHAPTER SOLUTIONS

NARROW IT DOWN: MULTIPLE-CHOICE QUESTIONS

1. (**b**) It is inefficient to express a two-digit number in scientific notation, for example, 50 as 5.0×10^1.
2. (**c**) The coefficient 14 holds the one place to the left of the decimal point in standard scientific notation.
3. (**b**) This is a large positive number; you must count from the last 0 to your left leaving one number in front of the decimal point.
4. (**d**) An order of magnitude is a number rounded to the nearest power of ten.
5. (**d**) If x is four orders of magnitude $(10 \times 10 \times 10 \times 10)$ greater than y (1), then x is $10^4/10^0$ or $10^{4-(0)}$, which is 10^4, or 10,000 times larger..
6. (**c**) The size difference is $D_{\text{Sun}}/D_{\text{Earth}} = 10^9\text{m} / 10^7\text{ m} = 10^{9-7} = 10^2$, or two orders of magnitude.
7. (**d**) This answer should be 8, not 7. In other words, the gas giant Jupiter is 8 orders of magnitude larger than the size of a human. $10^8/10^0 = 10^{8-(0)} = 10^8$
8. (**a**) There are seven orders of magnitude between the diameter of the Sun and the typical distance between stars. $D^*/D_{\text{Sun}} = 10^{16}\text{ m}/10^9\text{ m} = 10^{16-9} = 10^7$
9. (**c**) In other words, the human being is six orders of magnitude (6 powers of 10) taller than a grain of dust: $10^0/10^{-6} = 10^{0-(-6)} = 10^6$
10. (**d**) This is exemplified by the brief illumination of the monument's central chamber on the day of the winter solstice.

11. (**b**, **c**, **e**) The size difference is $10^{24}/10^{23} = 10^1 = 10$.
12. (**a–d**) The point of this question is that science is important in everything!
13. (**b**) 4.
14. (**e**) The human being is 10 powers of 10 bigger. $10^{0-(-10)} = 10^{10}$ m
15. (**d**) One of the earliest practical uses of astronomy was the planting of crops by the appearance of specific constellations.
16. (**a–e**) These are all characteristics of a pseudoscience.
17. (**d**) Any theory can be overturned if the evidence requires it.
18. (**c**) The usual starting point for the scientific method is an observed phenomenon followed by an educated guess (hypothesis), repeated experimentation, recorded results, and then a carefully constructed proposition that explains every piece of data (theory).
19. (**False**) Statistical analysis shows no correlation between the two phenomena.
20. (**True**) The laws of physics are the same everywhere in the Universe.

TO THE POINT: QUALITATIVE AND DISCUSSION QUESTIONS

21. As science continues to evolve, astronomers and other scientists are willing to modify or update their findings based on new data.
22. An aspect of modern science that is not accounted for is one's intuition or flashes of insight, although this phenomenon can lead to a hypothesis and ultimately a new discovery by accident.
23. Pseudoscience makes claims that cannot be substantiated nor refuted through the scientific method. On the other hand, scientific ideas provide evidence or facts by repeatable experimental results.
24. Science has a specific language just like any other discipline. Because most people are afraid of science, experts would need to communicate how to acquire scientific knowledge in layman's terms. Suggestions of books or articles would break down the process for the layperson. In this way, both sides share a common goal.
25. The criteria for a successful scientific theory are a carefully constructed proposition that explains the data, and that has been repeatedly tested and confirmed through observation and experimentation.
26. Science has benefitted humankind in several ways: (1) modern medicine has eradicated diseases allowing a person to live a long, healthy life, (2) transportation advances and rapid communication via the Internet have connected people and resources more efficiently, and (3) astronomical observations have helped us gain a better understanding of the Universe.
27. As a result of technological advancement, the world faces many challenges, such as climate change, depletion of resources, exhaustion of many of the world's fisheries, the threat of the use of nuclear weapons, and biological terrorism.
28. What is death? Does God exist? These questions go beyond ordinary physics into the metaphysical realm.
29. The basis for astrology is making predictions derived from the apparent positions of the Sun, Moon, and planets among the constellations and their influence on our lives. In contrast, astronomy is a modern science born out of astrology that provides explanations for observed phenomena and teaches us about the Universe.
30. At Newgrange, people were able to mark the winter solstice as the Sun lit the 24-meter passageway and the central chamber once a year. The Moon also marks the calendar in its monthly cycle of 29½ days. The constellations signaled both the passage of a month and the Babylonian calendar year of 12 months. Astronomical observations benefited ancient societies by helping them keep track of time and seasons for practical purposes, including agriculture, religion, and ceremonies and as an aid to navigation.
31. Depending on the time of year and your longitude, the next solstice you experience will either be the summer solstice (approximately June 21) or the winter solstice (approximately December 21).
32. It is a known fact that burning fossil fuels increases the levels of CO_2 in the atmosphere. Carbon dioxide concentration levels have risen since the 1800s from 275 ppm to 380 ppm today. This in turn has impacted our planet. Scientific data shows us an increase in global temperatures (1.5°F or 0.8°C) over the past 150 years, changes in rainfall patterns and biological habitats, and a rise in sea level that will create climate refugees. What can't be predicted are the long-term effects that climate change will have on our planet over the next century.
33. The night sky is our own window into space and time. How did the vast universe come to be, and where are we going? We now know that the expansion of the Universe is accelerating.
34. Selection bias is a phenomenon in which an individual in the process of making a choice preferentially notices and pays more attention to instances related to that choice. An example is a person shopping for a car selectively noticing cars of the specific makes and models being considered.

35. Answers may vary. One might disagree with Martin Rees's statement that humanity has a 50-50 chance of making it into the next century because of science's ability to empower both individuals and societies to make informed decisions. Ingenuity and necessity have always been the mother of invention.

GOING FURTHER: QUANTITATIVE QUESTIONS

36. **Set up:** Add a decimal point behind the last zero and count the number of zeroes leading up to the coefficient.
Solve: 200,000.
2.0×10^5 years
Review: Scientific notation is a shorthand way to write very large or small numbers.
37. **Set up:** One hundred years ago is 1.0×10^2.
The end of the last ice age occurred 10,000 or 1.0×10^4 years ago.
Solve: $10^4/10^2 = 10^{4-(2)} = 10^2$
Review: There are two orders of magnitude between the last ice age and one hundred years ago.
38. **Set up:** The diameter of Jupiter is about 10^8 m.
The diameter of Earth is 10^7 m.
Solve: $D_{\text{Jup}}/D_{\text{Ear}} = 10^8\ \text{m}/10^7\ \text{m} = 10^{8-7} = 10^1$
Review: Jupiter is 10 times larger than Earth.
39. **Set up:** The size of a dust particle is 10^{-6} m.
The size of a proton is 10^{-15} m.
Solve: $$\begin{aligned}\text{Dust particle/proton} &= 10^{-6}\ \text{m}/10^{-15}\ \text{m}\\ &= 10^{-6-(-15)}\\ &= 10^9\end{aligned}$$
Review: A proton is nine orders of magnitude smaller than a dust particle.
40. **Set up:** 1,500 generations would represent how many years?
Each generation on average is 25 years.
Solve:
$$\begin{aligned}1{,}500\ \text{generations} \times \frac{25\ \text{years}}{1\ \text{generation}} &= 37{,}500\ \text{years}\\ &= 3.75 \times 10^4\ \text{years}\end{aligned}$$
Review: The text states that the average number of years in a generation is 25. The word *each* in a word problem means multiply.
41. **Set up:** The size of a planetary system is 10^{13} m.
The size of our Milky Way Galaxy is 10^{21} m.
The size of an atom is 10^{-10} m.
The size of a proton is 10^{-15} m.
Solve: $$\begin{aligned}\text{galaxy/planetary system} &= 10^{21}\ \text{m}/10^{13}\ \text{m}\\ &= 10^{21-13}\\ &= 10^8\\ \text{atom/proton} &= 10^{-10}\ \text{m}/10^{-15}\ \text{m}\\ &= 10^{-10-(-15)}\\ &= 10^5\\ \text{G/PS vs. atom/proton} &= 10^8/10^5\\ &= 10^{8-5}\\ &= 10^3\end{aligned}$$
Review: The number of powers of 10 between the sizes of the galaxy and planetary system is larger by three orders of magnitude.
42. **Set up:** *Homo sapiens* first appeared on Earth 300,000 (3.0×10^5) years ago. Modern humans, defined as culturally and anatomically correct, appeared 200,000 (2.0×10^5) years ago.
Solve: $2.0 \times 10^5/3.0 \times 10^5 = 2/3 = 0.67$
Review: The ratio of time between modern humans and *Homo sapiens* is 2:3.
43. **Set up:** *Homo sapiens* first appeared on Earth 300,000 (3.0×10^5) years ago.
Solve: There are five orders of magnitude (i.e., five powers of ten) separating us from the first *Homo sapiens*.
Review: Since this is an order of magnitude question, we ignore the coefficient out front and simply take the exponent as the answer.
44. **Set up:** A million billion billion written in scientific notation
Solve: $10^6 \times 10^9 \times 10^9 = 1.0 \times 10^{24}$
Review: In scientific notation, when numbers are multiplied, the exponents are added.
45. **Set up:** Copernicus published his Sun-centered model in 1543. The number of seconds that have passed to the end of 2019 would be:
Solve: $2019 - 1543 = 476$ years
$$\begin{aligned}476\ \text{years} \times \frac{365\ \text{days}}{1\ \text{year}} \times \frac{24\ \text{h}}{1\ \text{day}} \times \frac{60\ \text{min}}{1\ \text{h}} \times \frac{60\ \text{s}}{1\ \text{min}}\\ = 1.50 \times 10^{10}\ \text{s}\end{aligned}$$
or, use the hint: 3.16×10^7 s/year
$$476\ \text{years} \times \frac{3.16\ \times 10^7\ \text{s}}{1\ \text{year}} = 1.50 \times 10^{10}\ \text{s}$$
Review: There are several ways in which to approach this problem. If a hint was not given, the student would have to rely upon his or her knowledge of units of time. This is time-consuming but puts units of time into perspective; both ways check the other.

LEARNING ASTRONOMY BY DOING ASTRONOMY

The following activities are available in the *Learning Astronomy by Doing Astronomy: Collaborative Lecture Activities* workbook. Each LADA activity is designed and classroom-tested to illuminate a particular astronomical concept or principle. LADA is available for purchase as a stand-alone or packaged with a Norton astronomy textbook at no extra cost.

Activity 2: Designing a Scale Model of the Solar System (LG 1.2)

In this activity students will learn how to create a scale model of the Solar System. After completing this activity, they will be able to

- calculate the scale factor for the relative sizes and distances used in the model.
- apply the scale factor to missing quantities.
- locate the eight major planets along the model Solar System route.
- summarize the steps used in creating a scale model.
- use the metric system and scientific notation.