Chapter 1: Charting the Heavens
The Foundations of Astronomy

Outline

Summary

Chapter 1 begins with a "Big Picture" overview of our place in the Universe. This is followed by a brief introduction to the science of Astronomy and the definition "Universe." Common units of measurement important to astronomers are introduced along with the convention of scientific notation. The scientific method is discussed giving the student an understanding of some of the differences between science and pseudo-science or non-science such as religion.

Constellations and the celestial sphere are introduced, which serve as a springboard to discussions of the apparent daily and annual motion of celestial bodies such as the Sun, Moon, and stars. The nature and history of the modern calendar is presented. Finally, solar and lunar eclipses are introduced and the chapter concludes with the concept of parallax and its use in performing measurements of distance and size.

Major Concepts

- The Big Picture – Our Place in the Universe
- The Universe
- Astronomy
- Scientific Theories
  - Testable
  - Simple
  - Elegant
- The Scientific Method
  - Observation
  - Hypotheses/Explanation
  - Observation/Experimentation
- Constellations
- The Celestial Sphere
- Earth's Motion
  - Rotation about its own axis (daily motion)
  - The tilt of the axis
  - Revolution around the Sun (yearly motion)
  - Zodiac
  - The Seasons
    - Solstices
    - Equinoxes

    - Precession
- Timekeeping
    - Meridian
    - Time Zones
    - Origin of the Modern Calendar
    - Leap Year
- The Moon's orbit
    - Lunar phases
    - Lunar eclipses
    - Solar eclipses
- Distance
    - Triangulation
    - Parallax

Teaching Suggestions and Demonstrations

One of the challenges in studying astronomy is developing the ability to view the universe from different perspectives, primarily the perspective we have from Earth, where we see the Sun and stars rise in the east and set in the west, and the perspective from "outside," where we "see" Earth spinning on its axis and orbiting the Sun. Use plenty of models and diagrams in teaching this introductory material in order to help your students practice shifting viewpoints. Lots of new vocabulary is introduced in this chapter; take the time to define new terms.

This will likely be your students' first exposure to a formal class in astronomy. They will come to the class with some knowledge, misinformation, and misconceptions derived from years of exposure to multimedia sources. It is not unusual for people to believe some aspects of what they know as science fiction. Most students are still comfortable with Aristotelian thinking. This chapter provides your first opportunity to slowly move your students toward a new way of thinking; a new perspective. As listed below, the number of problem areas and misconceptions are numerous, especially in the earliest chapters of this text. This is to be expected. Students have few misconceptions about active galaxies because most have never heard of them.

Section 1.1

The **light-year** is almost universally confused by students as being a unit of time rather than distance. This confusion comes about simply because of the word "year." Spend some time discussing a light-year by first introducing the **speed of light**. Tell them that light travels at a (non-infinite) speed and therefore requires time to travel a given distance. Emphasize "distance" here. Since the speed of light is about 3×10^5 km/s, one light-second is 3×10^5 km, a distance. Next, describe a few examples such as the fact that light travels fast enough to go around the Earth more than seven times in one second; therefore, one light-second is equivalent to a bit more than seven times the circumference of the Earth. Another example is that the Sun is about 8 light-minutes away. Students are usually intrigued by the idea that if the Sun were to burnout or explode right now, then we would have no way of learning that fact for another 8 minutes. Finally, use the distance to far away galaxies as another example. The galaxies are so *distant* that it takes millions of years for their light to reach us. Therefore they are millions of light-years away. This is good conceptual foreshadowing for things to come later in the semester. When we look at distant objects, we see them as they were when their light left them. The Sun appears to us as it was 8 minutes ago. Distant galaxies appear to us as they were millions of years ago. When we look at distant objects, we effectively are looking back in time.

Section 1.2

Since many of your students are likely to have had minimal exposure to science, this section is worthwhile focusing on for class discussions. In introducing the **scientific method**, refer to Figure 1.6 now as well as throughout the semester. Remind the students that science is a *process* rather than some fixed set of ideas or laws. This is a STRENGTH, not a weakness. Its strength rests on the fact that it does not rely on the authority of political or religious systems nor on the interpretation of text, ancient or otherwise. Ask the students to provide examples of ideas in their own minds that had changed once additional data or knowledge had become known to them.

Section 1.3

Your students will all have heard of **constellations** and will probably be able to name at least a few. I usually begin my discussions of constellations by simply asking the students "How many constellations are there?" The most common response is invariably "twelve." They are often surprised to learn that there are in fact 88. Emphasize that the stars in a given constellation are probably not physically close to each other in space; they just appear close to each other as seen from Earth. The stars in each constellation were grouped together by observers in ancient times, and we continue to use nearly the same groupings today. You can pass out or project a sky chart without constellations drawn in and challenge students to make up their own. I once had a student create the constellation "sock lost in the dryer." (She even came up with a myth to explain why the gods had flung the sock to the sky!)

It is also interesting to compare names of northern and southern constellations. The northern constellations are typically named for animals and mythological characters. The Southern Hemisphere sky includes constellations such as the telescope, the microscope, and the octant. Ask your students if they can explain the difference. The **constellation names** we have inherited today derive from northern observers. The northern constellation names, therefore, date from ancient times, but the southern ones date from the early travels made by northern explorers to the Southern Hemisphere.

If you have time, explain a few of the **myths** that involve whole families of constellations. The story of Orion, Taurus, and the Pleiades is a good one, as is the story of Cassiopeia, Cepheus, Andromeda, Cetus, and Perseus. These are all constellations your students can find in the night sky, depending on the time of year you are teaching the course. Provide star charts and encourage your students to find major constellations in the night sky throughout the course.

The concept of the **celestial sphere** is an important one. We are missing *depth perception* when we look out at the night sky. ➲ **DEMO** If you have one, bring in a transparent model of the celestial sphere with Earth inside and point out the **north and south celestial poles** and **the celestial equator**. This is a good time to discuss Polaris and clear up any misconceptions; often, introductory astronomy students believe the North Star must be the brightest star in the sky.

Introduce students to **right ascension** and **declination** by comparing these to latitude and longitude. Emphasize that the celestial coordinates are attached to the sky. Over the course of a night, stars move from east to west and the coordinate system moves with them. Look up the coordinates of a few well-known stars (including Polaris) and help students determine their positions. Ask students to compare the two different methods of describing star locations, by coordinates and by constellation, and discuss the advantages of each.

Section 1.4

Students usually know the terms **rotation** and **revolution** but often confuse them, so take a few moments to define these terms. Likewise, they will probably know that Earth takes a day to turn on its axis and a year to orbit the Sun, but will not know the difference between a **solar day** and a **sidereal day**, or a **tropical year** and a **sidereal year**. Use lots of diagrams, such as Figure 1.13, to help explain. Models also help. ➲ **DEMO** Demonstrate rotation and revolution with globes, or bring students to the front of the class to model Earth's motions. For instance, one student can spin around (slowly) while also orbiting another. Ask the class to concentrate on one point on the Earth, say, the spinning student's nose, and imagine when it is lit and when it is dark. Use this model to explain day and night, sidereal vs. solar days, and why different constellations are visible in the night sky during different months.

Figures 1.15 and 1.16 are very important and particularly insightful when used in conjunction with one another. Make sure students understand that Figure 1.16 shows the ***apparent* path of the sun** on the celestial sphere and that this path passes through the constellations of the **zodiac**. At this point I usually repeat the question from Section 1.3 above, but this time I ask "O.K., so how many constellations are members of the zodiac?" Again, the common answer will be "twelve." Although this is true for the "astrological zodiac," they are usually surprised to learn that there are actually 13 zodiacal constellations, including Ophiuchus. Show a list of these constellations along with the modern dates during which the Sun appears in each. Ask the students if they notice any "errors" in the dates. There will be several that mention that their birthdays do not fall within the dates shown for their astrological "sign." This usually serves as a perfect lead-in to the history of the modern calendar including the concept of **precession**.

➲ **DEMO** A gyroscope or top in motion on a table or desk makes a good demonstration of **precession**. Precession is responsible for the fact that the zodiac constellations no longer correspond to their astrological dates. The heliacal rising of Sirius, in the constellation Canis Major, was an important date in the ancient agricultural calendar, but this no longer occurs on the same date today.

Use models of Earth and the Sun (or just two spheres) to help explain how Earth's tilt changes the position of the Sun in the sky as Earth orbits the Sun. Emphasize that the **solstices** and **equinoxes** can each refer to both a point in time *and* a point in space. The summer solstice, for instance, is the point on the ecliptic where the Sun is at its northernmost point, but we also use the term to refer to the time and day when the Sun is at that point. Students will be most familiar with the latter meaning, and know that the summer solstice occurs around June 21.

Begin your discussion of **seasons** with an informal, multiple-choice pre-quiz. Ask students what causes the seasons, and include in the answer choices both the correct response, namely, Earth's tilt, and a common misconception, the distance from Earth to the Sun. If significant numbers of students choose the distance answer, make sure you address this misconception and explain why the different distances from Earth to the Sun do not affect the seasons. Many students are surprised to find that, in fact, the Earth is *farthest* from the Sun during the Northern Hemisphere summer. Bring in a flashlight and shine it directly down on a tabletop or on the floor, and then shine it at an angle to show how the angle of the Sun's rays affect solar heating. Go back to your model of Earth orbiting the Sun to show how the length of time the Sun is up in the sky also changes as the seasons change.

Section 1.5

Referring to Figure 1.20, explain why someone in California, for example, is three hours "behind" someone in New York. Also, remind the students that the time-zones are a human construct. Their existence is based on convention, convenience and the fact that the Earth rotates once in approximately 24 hours. There are 24 time zones and they are incremented by one hour from one to the next, but the boundaries between them have been drawn with local and cultural factors in mind. For example, the industrial region of Detroit is in the Eastern time zone primarily because there was a desire to have the factories open and close with Wall Street, which is located far to the East in New York. For this reason, people in Detroit may not see the sunset until nearly 10:00 p.m. during the heart of summer. Of course, this is when **daylight savings time** is in effect, which brings us to another time-keeping issue based on cultural factors.

Section 1.6

➲ **DEMO** When explaining the motions of the Earth, Moon, Sun, and stars you can bring a common Earth globe (unmounted) to class. To represent the Sun use a light bulb or, preferably, an overhead projector. For the Moon, any sphere with a quarter diameter of the Earth globe for will work well (softballs or baseballs often work well for some globes), and a flashlight to demonstrate seasonal effects of the Sun. Let the students be the stars!

Start your discussion using the globe upside down. Some brave or frustrated student will inevitably question why you are doing this. It is a perfect lead-in to discussing what is up and down in space and how orientations are arbitrary but necessary to define. Use the equator, direction of the poles, and the ecliptic as locations that do not vary in orientation (or at least do so very slowly). Demonstrate the normal orientation of the Earth and the directions of the Earth's rotation, lunar revolution, and Earth orbital motion.

Don't assume your students actually understand the phases of the Moon. After defining the four basic phases ask questions such as "At what time of day or night is the first quarter moon the highest in the sky?" Sunset. Demonstrate this with your model. ➲ **DEMO** Use a miniature doll as your observer and place it on the Earth globe surface while you rotate the Earth. It is difficult for many students to change their frame of reference to that of your model. If there is a laboratory component to your course, using such simple models can be very instructive and surprisingly satisfying to students.

The *terminator* is the line between day and night. Notice that the terminator on the Moon (see Figure 1.21) appears curved much of the time. Why is this? Show in your demonstration that this is due to the curved shape of the Moon.

➲ **DEMO** To demonstrate eclipses, use the same Earth globe and sphere for the Moon. Now set up a true scale model of this system by placing the Moon at 30 Earth diameters from the Earth. Establish the plane of the ecliptic and raise and lower the Moon by ±10 of its diameters to demonstrate the range of its inclination to the ecliptic (which is ±5° and the Moon is about 0.5° in diameter). It is not possible for any textbook picture or diagram to realistically represent the Earth-Moon system to scale.

With this model, students will see how easy it is for the lunar shadow to miss the Earth during the new Moon phase or how the Moon misses the Earth's shadow during full Moon phase (the Earth's shadow being about 2.5 lunar diameters). When describing eclipses, ask the students what would be seen if they stood on the Moon's surface while looking in the direction of the Earth or the Sun. Would the lunar surface be in darkness or light? What about the Earth or Sun? Remember that the Sun will appear to be the same size in the sky but the Earth will appear four times larger in diameter than the Moon does from Earth. Show photographs of both lunar and solar eclipses, including partial, total, and annular solar eclipses.

Section 1.7

➲ **DEMO** Figure 1.32 illustrates an excellent demonstration of **parallax** that you can have your students try in class. Instruct them to hold up a finger (or pencil), close one eye, and line their finger up with some object on the far wall of the classroom. When they sight on their finger with the *other* eye open instead, it lines up at a different position. Ask students to try the exercise several times with their finger at different distances from their eyes to determine the relationship between the distance and the amount of shift. ➲ **DEMO** A second method of demonstrating parallax is to make marks on the board representing the fixed stars. Hold a small ball about one meter or so in front of the board. With your other hand, prepare to make a mark on the board at the location given you by two students at the opposite sides of the back of the room. Select a student in the back left part of the room and have them tell you where they see the ball relative to the background stars. Make a mark on the board corresponding to that location. Repeat the procedure by selecting a student at the back of the room on the right side. The two apparent locations will be distinctively different allowing for a clear demonstration of the concepts related to the geometrical foundations of parallax, namely baseline and parallax angle. Figure 1.31 shows this method applied to astronomy using Earth's diameter as a baseline. Challenge students to come up with a method where observers restricted to the surface of Earth can create an even longer baseline in order to measure parallaxes of more distant stars. (Observations can be made at different points in Earth's orbit around the Sun.) Even with the diameter of Earth's orbit as a baseline, the parallax method only works for the stars in the solar neighborhood.

Angular measure is very important to astronomy. Discuss *More Precisely 1-1* carefully. ➲ **DEMO** Demonstrate angular measure by holding up a penny. At a distance of about 1 meter, a penny subtends an angle of about 1 degree. Students can hold up a penny and see what objects at different distances in the classroom have an angular size of about 1 degree. Also have students try this at night and estimate the angular size of the Moon, half a degree.

More Precisely 1-2 discusses finding the **distances** to (and diameters of) astronomical objects. Go over angular measurements and then try several examples. Many problems throughout the text use the equations in this section, so it is worth spending some time with them to ensure student understanding.

Student Writing Questions

1. What is the smallest object you have ever seen? The largest? The longest distance you have ever traveled? What is the largest number of objects you have ever knowingly encountered? (You may encounter lots of bacteria, but not knowingly.) What was the longest you ever spent doing one activity? How do the largest and the smallest of these compare? How do the distances compare to the size of the Earth? To the distance to the Moon? How does your time spent compare to your lifetime?

2. Describe the room in which you do most of your studying in metric units. How big is it? What is the size of your desk? The TV or radio? How heavy are your books? The dimensions of your bed? Choose objects that have a range in sizes.

3. Test your horoscope. Each day, write two or three sentences of the most significant events that occurred to you that day. Cut out or copy your horoscope for that day and save. Continue this every day for about three weeks and make sure you write down your daily events before you read the horoscope. After three weeks, check what you wrote and your horoscope for each day and see if there is a match. Count the number of "hits" and

"misses." Discuss the results and whether there is any significance to the number of hits. Are horoscopes truly predictive?

4. Describe an ordinary situation in which people regularly apply the scientific method, even though they are not aware they are doing so. Relate the situation to the three basic steps in the scientific method: gather data, form theory, and test theory.

5. Find a location to view the night sky with little interference. Do this on as clear a night as possible. What do you see? Look all over and make note of the brightest stars. Are there any planets? How can you tell? Is the Moon out? What does it look like? What sort of details can you see on its surface?

Answers to End of Chapter Exercises

Review and Discussion

1. As given in Appendix 1, the Sun is about 100 times the size of the Earth. From Section 1.1, a light-year is about 10^{13} km and a typical galaxy is about 100,000 Ly in diameter, or 10^{18} km. This makes a galaxy about 10^{14} times larger than Earth. Astronomers can see objects as distant as 10 billion LY or 10^{23} km or 10^{19} times larger than Earth.

2. The "universe" is the totality of all space, time, matter, and energy.

3. A light-year is the distance traveled by light in a year, about 9.5 trillion kilometers.

4. The scientific method is the method by which scientific theories are created and tested, then altered if necessary. Observations lead to hypotheses or theories, which provide explanations and the means through which to make predictions. Experiments are then performed or observations are made to test these predictions. If the predictions turn out to be incorrect, then the theory is modified or discarded. Religion, on the other hand, often relies on decree by authority or on personal revelation, neither of which are testable. If a claim is not testable, then it cannot be accepted as science.

5. Constellations give names to different sections of the sky, much like names of countries are used to name different sections of the Earth. They are useful in naming objects in those locations.

6. Although the Sun appears to rise in the east and set in the west, in fact the Sun is stationary relative to the Earth. The Earth rotates from west to east, giving rise to this apparent motion of the Sun. The Moon, stars, and all other astronomical objects appear to do the same because we view them from the surface of the rotating Earth.

7. The true rotation of the Earth is measured with respect to the stars, the sidereal day. But during that interval of time, the Earth has moved in its orbit around the Sun. In order for the Sun to appear in the same location as it did on the previous day, the Earth must rotate slightly more. The solar day is slightly longer than the sidereal day. Refer also to Figure 1.10.

8. Since the Earth moves around the Sun once in a year, the number of times you have traveled around the Sun equals your age in years.

9. Due to the yearly motion of the Earth around the Sun, in the summer the Earth points in a direction 180° opposite of the direction it points during the winter.

10. The seasons of the Earth are caused by the tilt of the Earth's equator relative to its orbit around the Sun. This results in the Sun appearing higher in the sky during spring and summer months and causes higher rates of heating. In the fall and winter months the Sun appears much lower in the sky, its light falling more at an angle to the Earth's surface, and heats it less.

11. Precession is a slow shift in the direction of the tilt of the Earth's axis of rotation. Over a period of 26,000 years the axis moves through a circle, always keeping an angle of about 23.5 degrees. It is caused by the gravitational pull of the Moon and Sun.

12. Standard time zones are merely a convenience. Since the world's population is scattered around the globe, time zones allow for means of keeping local time in step with the locally observed daily motion of the Sun. Tradition holds, for example, that Noon is the time of day when the Sun is high in the sky (near the meridian). Leap years are similar in that they exist in order to maintain congruence between the Earth's seasons and a public way of keeping time (i.e. the calendar).

13. As the Moon orbits around the Earth, different sides of it are illuminated by the Sun. In addition, our angle of view of the Moon changes during its orbit around us. The result is that we see a fully illuminated Moon (full phase), to a non-illuminated Moon (new phase), to everything in-between.

14. A lunar eclipse is caused by the Moon entering the shadow of the Earth. A solar eclipse is caused by the Earth entering the shadow of the Moon.

15. A lunar or solar eclipse occurs only if there is a relatively precise alignment of the Sun, Earth, and Moon. But the Moon's orbit is tilted 5.2° to the orbit of the Earth. Each month, during full or new lunar phase, an eclipse of the Moon or Sun does not occur because the Moon is not in the ecliptic. Twice a year the Moon crosses the ecliptic when it is at one of these phases and an eclipse will likely be seen.

16. It would be easy for an observer on another planet to view lunar eclipses, as long as the moon or moons enter into the shadow of the planet. Solar eclipses are a bit more tricky in that the moon must cover the Sun sufficiently to block it out. This is certainly possible, depending on the size of the moon and its distance from the planet (and the Sun's distance from the planet).

17. Parallax is the apparent change in position of a foreground object, relative to distant background objects, due to the change in the position of the observer. Example: look at your finger with one eye and then the other. Notice how your finger seems to move relative to distant objects in the background.

18. The amount of parallax depends directly on the length of the baseline and inversely on the distance to an object. Because objects in astronomy have such large distances, a long baseline is required in order to make the parallax measurable.

19. The information needed to measure the diameter of a distant object is the distance to the object and the angular diameter of the object.

20. Stars in constellations have only their direction in the sky in common. They may be separated by vast distances. From within the solar system, their positions would look very much as they do from Earth. From the nearest star there would likely be some noticeable shift in the positions of stars within some constellations. From the center of the Galaxy, none of our familiar constellations would be visible.

Conceptual Self-Test

1. T
2. F
3. T
4. F
5. T
6. F
7. T
8. F
9. T
10. F
11. B
12. B
13. D
14. A
15. C
16. A
17. C
18. C
19. A
20. D

Problems

1. Light travels at about 300,000 kilometers in a second.

   (a) 500 / 300,000 = 0.0017 s.
   (b) 10,000 / 300,000 = 0.033 s.
   (c) 400,000 / 300,000 = 1.3 s.
   (d) $0.3 \times 150{,}000{,}000 / 300{,}000 = 150$ s.
   (e) $3.1\times10^{13} / 300{,}000 = 10^{8}$ s = 3.3 yr.

   So, the correct answer is (d) The Moon.

2. (a) $1000 = 1\text{x}10^{3}$; $0.000001 = 1\text{x}10^{-6}$; $1001 = 1.001\times10^{3}$; $1{,}000{,}000{,}000{,}000{,}000 = 1\text{x}10^{15}$; $123{,}000 = 1.23\times10^{5}$; $0.000456 = 4.56\times10^{-4}$.

   (b) $3.16\times10^{7} = 31{,}600{,}000$; $2.998\times10^{5} = 299{,}800$; $6.67\times10^{-11} = 0.0000000000667$; $2\times10^{0} = 2$.

   (c) 2000.01; 333,000; 9.47×10^{12}.

3. Due to Earth's orbital motion, it must now rotate for an additional 4 minutes for the Sun to come back into its same position as on the previous day. If the Earth's rotation were

reversed, it would have to rotate 4 minutes less in order to put the Sun in the same position. The net effect would be a day 8 minutes shorter than the current one.

4. The year 10,000 A.D. is about 8,000 years from now. Compared to the precession period of 26,000 years, this is 0.31 of a complete circle or 111°. With 12 constellations in the zodiac, their spacing is approximately 30° apart. The 111° degrees converts to 3.7 constellations. Using Figure 1.12, if the vernal equinox is now just entering Aquarius, it will be well into Scorpio by 10,000 A.D.

5. (a) In 7 days, the Moon would complete one sidereal month. But because the Earth has moved in its orbit, the Moon will have to revolve a little further in order to get back to its original orientation with the Sun and Earth. In 7 days, the Earth has moved approximately 7°; the Moon will have to move that same amount in its orbit. The amount of time that will take is simply 7/360 = t/7 or 0.14 days. So, the month would be 7.14 days long.

   (b) The easiest way to visualize this is to start with the Sun, Earth, and Moon lined up in that order. In one quarter of a year, the Earth will have moved 90°. But the Moon will also have moved 90°. Relative to the Earth, the Moon is not changing its position; the order is still Sun, Earth, and Moon. So there would be no month; the Moon would remain at a constant phase.

6. Because the Moon appears to orbit the Earth in 29.5 days, it appears to move about 12° per day.

   (a) In one hour it moves 0.5° = 30'.

   (b) In one minute it moves 0.5' = 30".

   (c) In one second it moves 0.5". Because the Moon's diameter is about 30', it moves its own diameter in about one hour.

7. The Moon is 384,000 km away from Earth. Calculate the circumference of its orbit and divide by its period, 27.3 days, in seconds.
   $2 \times \pi \times 384{,}000$ km / 27.3 days $\times$ 24 hr/day $\times$ 3600 s/hr = 1.02 km/s

8. Simple trigonometry gives this distance to be (250)tan(30°) = 144 m. Students may need to do this graphically, however.

9. Using the method given in *More Precisely 1-4* we have (a) 1° / 360° = 1000 km / $2\pi D$. Solving for D gives 57,300 km.

   (b) 1/60° / 360° = 1000 km / $2\pi D$ gives $D = 3.44\times10^6$ km

   (c) 1/3600° / 360° = 1000 km / $2\pi D$ gives $D = 2.06\times10^8$ km.

10. Using the method given in *More Precisely 1-4* we have to change the 57.3° to arc seconds = 206,000". Diameter = 45,000,000 km × 55" / 206,000" = 12,000 km.

11. Again, from *More Precisely 1-4* we find that parallax = baseline × 206,000" / distance, where 57.3° has been converted to arc seconds. The baseline = 12,800 km and the light year = 9,500,000,000,000 km (Review Question 3.) The result is 0.000065".

12. Assuming a 2 cm thumb at a distance of 75 cm gives $2 \times 57.3° / 75 = 1.5°$.

13. Since the angular diameters are the same, the ratio of the Sun size to the Moon size will be simply the ratio of their distances, 150,000,000 km / 384,000 km = 391.

14. $2 \times \pi \times 150{,}000{,}000$ km / (365.24 days × 24 hr/day × 3600 s/hr) = 30 km/s. In an hour it will be 108,000 km. In a day it will be 2.6×10^6 km.

15. The Sun would not have changed positions had the Earth been flat. Therefore, Eratosthenes would have measured an angle of zero.

Resource Information

Student CD Media

Movies/Animations
The Earth's Seasons

Interactive Student Tutorials
Stellar Parallax

Physlet Illustrations
Solar vs. Sidereal Day
Angular Measurements vs. Distance Measurements
Lunar Phases
Eclipses

Transparencies

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Suggested Readings

Allen, Richard Hinckley. *Star Names: Their Lore and Meaning*. Dover Publications, New York. A reprinting (with corrections) of a work first published in 1899. It has fascinating information and more detail than you will ever need to know.

Berman, B. "The Outsider." *Astronomy* (October 2003). p. 48. Illuminating article about a modern astronomer. Helpful when discussing the scientific method with students and a good reminder that science is a human endeavor/activity. Relevant to this chapter and to chapter 2.

Berman, Bob. "Five-five-uh-oh." *Astronomy* (5 May 2000). p. 93. Discusses the effects of the "planetary alignment" of May, 2000, and provides arguments against astrology.

Brown, Jeanette. "It's just a phase." *Astronomy* (Apr 1999). p. 76. Describes an activity designed to demonstrate the phases of the moon.

Cunningham, C. J. "Updating Eratosthenes." *Mercury* (March/April 2003). p. 10. Discusses a method by which students can measure the size of the Earth using the internet.

Gurshtein, Alexander A. "In search of the first constellations." *Sky and Telescope* (June 1997). p. 46. A fairly detailed discussion of the origin and history of constellations.

Hiscock, Philip. "Once in a blue moon." *Sky and Telescope* (Mar 1999). p. 52. Discussion of the meaning of the term "blue moon."

Hobby, David. "Portrait of the shortest day." *Sky and Telescope* (6 June 1998). p. 46. Displays and discusses making a photograph of the Sun's path across the sky on the winter solstice.

Kanipe, Jeff. "Tilt-a-whirl astronomy: the seasons explained." *Astronomy* (Mar 1996). p. 50. Describes the apparent daily and annual motions of the Sun across our sky.

Krupp, E. C. "Slithering toward solstice." *Sky and Telescope* (6 June 2000). p. 86. Discusses the symbolism of snakes, serpents, and solstices.

Livio, M. "Is God a Mathematician?" *Mercury* (January/February 2003). p. 26. Brief discussion of the role played by mathematics in scientific theories.

Mayo, L. "Occult Astronomy." *Mercury* (November/December 2003). P. 13. Discusses occultation of celestial objects including the Sun and Moon.

Olson, Donald W; Sinnott, Roger W. "Blue-moon mystery solved." *Sky and Telescope* (3 Mar 1999). p. 55. Discussion of the meaning of the term "blue moon."

Olson, Donald W; Fienberg, Richard Tresch; Sinnott, Roger W. "What's a blue moon?" *Sky and Telescope* (5 May 1999). p. 36. Even more discussion about the interesting history of the term "blue moon."

Panek, Richard. "The astrology connection." *Natural History* (3 Apr 2000). p. 20. Discusses conjunctions and the history connection between astrology and astronomy.

Paczynski, B. "Astronomy: A Problem of Distance." *Nature* (22 Jan. 2004). p. 299. An example of determining distances to astronomical objects (along with associated practical considerations).

Panek, Richard. "That sneaky solstice." *Natural History* (5 June 2000). p. 20. Describes the meaning of the solstice, and discusses why the earliest sunrise does not happen on the solstice.

Ryan, Jay. "SkyWise: equinox." *Sky and Telescope* (3 Mar 2000). p. 114. Comic strip drawing illustrating the equinoxes.

Ryan, Jay. "SkyWise: Gregorian calendar." *Sky and Telescope* (Feb 2000). p. 109. A cartoon strip showing systems of calendars.

Ryan, Jay. "SkyWise: lunar skies." *Sky and Telescope* (4 Apr 2000). p. 114. A cartoon strip illustrating the view of the Earth as seen from the Moon.

Sweitzer, J. "Do You Believe in the Big Bang?" *Astronomy* (December 2002). p. 34. Discusses "Theory" and evidence in general and as applied to the Big Bang Model.

Trefil, James. "Architects of time." *Astronomy* (9 Sept 1999). p. 48. Discusses history of astronomical time keeping, from Stonehenge to pulsars.

Notes and Ideas

*Class time spent on material: Estimated:*_______ *Actual:*______________

Demonstration and activity materials:

Notes for next time: