

Homework Assignment #5: The Moon

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Chapter 21 – Origins of Modern Astronomy

Motions of the Earth-Moon System (p. 617–620)

A. Introduction

1. Approximately how long does it take the moon to complete one full orbit around Earth?

2. Which way does the moon revolve around the earth?

B. Phases of the Moon

Definitions: The following terms define the various phases of the moon. Memorize these terms!

Full Moon	The moon is full when the side we see is 100% illuminated. A full moon looks like a perfect circle.
New Moon	The moon is new when the side we see is dark. We cannot see a new moon at all.
Crescent Moon	A crescent moon is shaped like a crescent; a smaller proportion of the moon is illuminated than is the case during a quarter moon.
Quarter Moon	The moon is called a quarter moon when it looks like a half circle ¹
Gibbous Moon	A gibbous moon is shaped like a lopsided football; a larger proportion of the moon is illuminated than is the case during a quarter moon.
Waxing Moon	The moon is waxing when the illuminated portion of the moon is getting a little bit bigger every day.
Waning Moon	The moon is waning when the illuminated portion of the moon is getting a little bit smaller every day.

¹ So then why is it called a quarter moon? Because it's 1/4 of the way around in its orbit.

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1. Questions About These Definitions: To find the answers to the questions below, consult your data from the moon project, the section in the textbook entitled *Phases of the Moon* (p. 618–619), and Figure 21.27 on p. 618.

a. How does a 1st quarter moon look different from a 3rd quarter moon? (Hint: think about whether they are lit on the right or left side)

b. How does a waxing crescent moon look different from a waning crescent moon?

c. How does a waxing gibbous moon look different from a waning gibbous moon?

2. The cause of the moon's phases:

a. Where does the moon get its light from? _____

b. What proportion of the moon is illuminated at any time? _____

c. What phase is the moon in when it lies between the Sun and Earth? Why?

d. What phase is the moon in when the earth lies between it and the sun? Why?

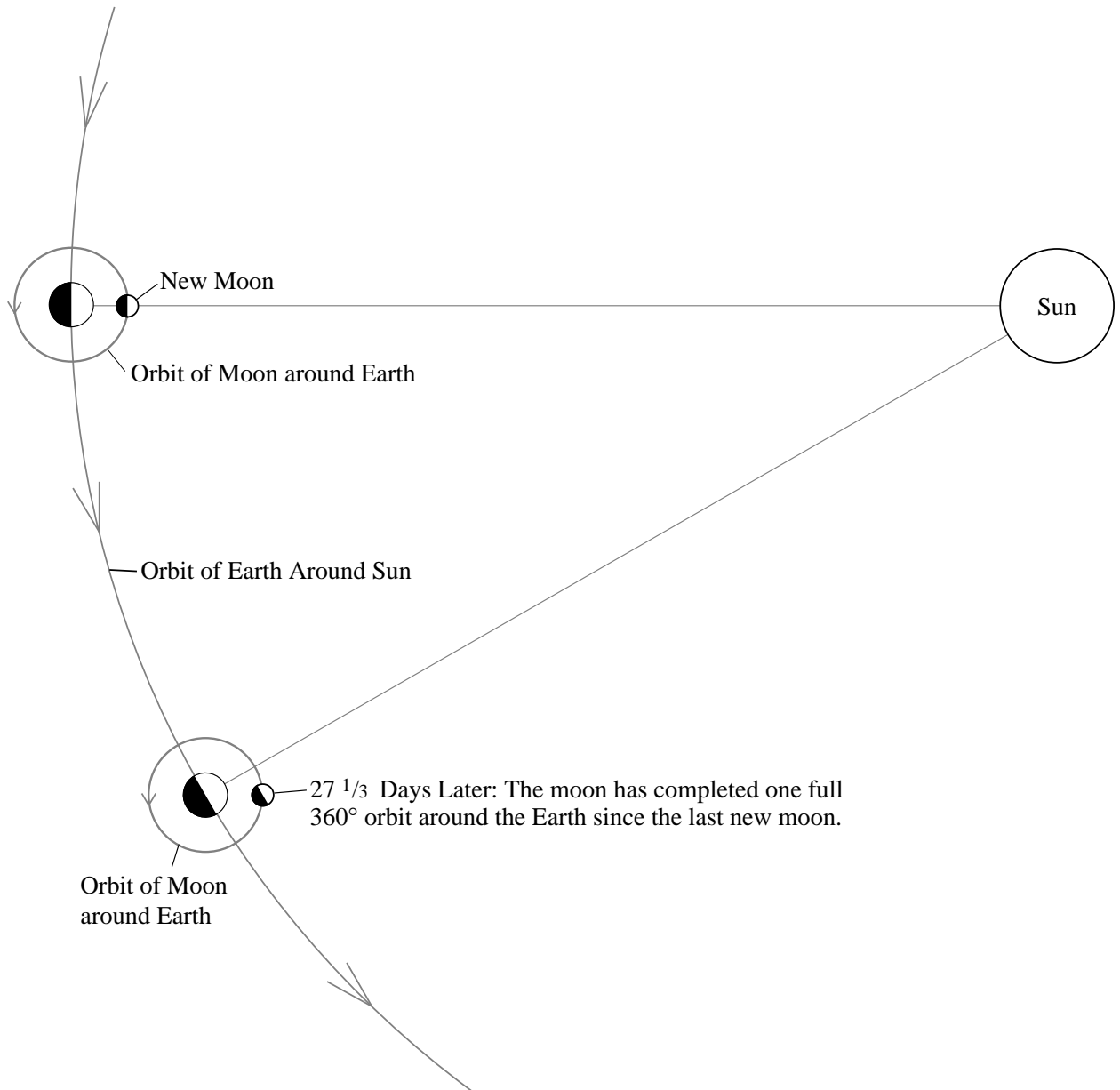
C. Lunar Motions (p. 617–618)

In addition to reading the text, carefully study the diagram on the next page--ignore Figure 21.26 on p. 617; it is VERY POORLY designed because it implies that the “distant star” is actually so close that it is inside of our solar system. I don’t think so!

1. *Synodic* Month: How long does it take the Moon to go through all of its phases?

2. *Sidereal* Month: How long does it take the Moon to complete one 360° revolution around Earth?

3. Why is a synodic month longer than a sidereal month? In answering this question, add to the diagram below.



4. Why do we always see the same side of the moon, no matter what phase it is in?
5. How long does daylight last on the moon? _____
6. How long does darkness last on the moon? _____

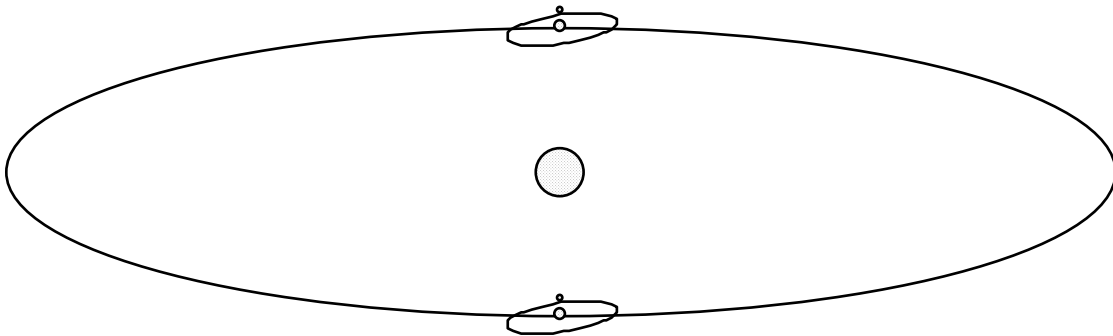
D. Eclipses of the Sun and Moon (p. 619–620)

1. What causes a solar eclipse? (See Figure 21.28 on p. 619)

2. What phase is the moon in during a solar eclipse? _____
3. What causes a lunar eclipse? (See Figure 21.29 on p. 620)

4. What phase is the moon in during a lunar eclipse? _____
5. Why does a solar eclipse not occur with every new-moon phase and a lunar eclipse with every full-moon phase?

6. The number of eclipses per year
 - a. How many solar eclipses do we usually get (somewhere on Earth) a year? _____
 - b. How many lunar eclipses do we usually get (somewhere on Earth) in a year? _____
 - c. Why these numbers? (Hint: see the diagram below.)



7. Why is the moon still visible, but copper-colored, during a full lunar eclipse?

8. Why do lunar eclipses last so much longer than solar eclipses?

Homework Assignment #6: Apparent Motions of the Heavens Due to Actual Motions of Earth

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Chapter 21 – Origins of Modern Astronomy

Positions in the Sky (p. 611-615)

A. The Celestial Sphere

1. What is the origin of the concept of the “Celestial Sphere?”
(In addition to reading the text, also study Figure 21.20 on p. 614.)

2. There really is no celestial sphere. So why do we still use the concept?

Constellations (p. 611–614)

A. What is the origin of the constellations that we use?

- B. Are the stars in any particular constellation ACTUALLY close together or do they just look that way? Explain, using a diagram to illustrate your answer.

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B. The Equatorial System

1. **Celestial Poles:**

- a. Figure 21.21 (p. 614) shows a time exposure of the sky, centered around the North Star. The curved lines are the trails made by stars as they appear to orbit the North Star. Why do all of the other stars seem to orbit the North Star? Draw a diagram to illustrate your answer.

- b. How are the North celestial pole and the Earth's North Pole similar? How are they different?

2. **Celestial Equator** (For an illustration, see Figure 21.20 on p. 614.): How are the Celestial equator and the Earth's equator similar? How are they different?

The Motions of the Earth (p. 615–617)

A. Rotation

1. How long does it take the earth to complete one full 360° rotation? _____
2. Why are our standard “days” longer than this? (In addition to reading the text, carefully study Figure 21.23 on p. 615.)

B. Revolution

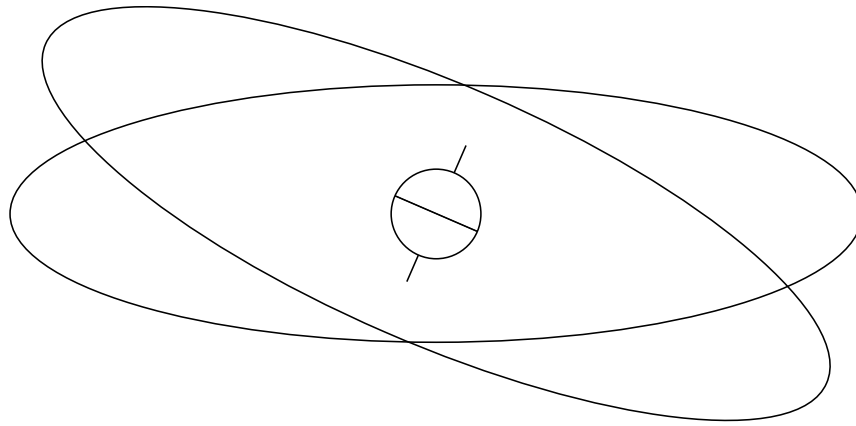
1. Apparent path of the sun
 - a. Over the course of a year, why does the sun appear to move relative to the stars? In addition to reading the text, carefully study Figure 21.C on p. 612.

 - b. Why is this apparent motion about 1° per day? (Hint: A circle has 360 degrees.)

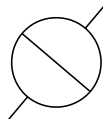
2. **Ecliptic** (Study Figures 21.24 on p. 616)
 - a. What is the ecliptic?

 - b. Why do the moon, sun and planets always lie on or very close to the ecliptic? (In addition to reading the text, carefully study Figure 21.C on p. 612.)

- c. The ecliptic does not line up with the celestial equator. Why not?
- d. Complete the diagram below, showing the ecliptic and the celestial equator in their correct relative orientations.
Hint: the book DOES NOT have a diagram that shows this exact configuration.



- e. If the Earth's tilt was 40° instead of 23.5° , how would the relationship between the celestial equator and the ecliptic be different? To illustrate your answer, complete the diagram below.



C. Precession (p. 616)

1. What is precession? In addition to reading the text, carefully study Figure 21.25 on p. 617.
2. How long does it take for Earth's axis to trace a complete circle across the sky?
3. Will Earth's axis always point toward Polaris (the North Star)? Explain.

Box 20.2 Astrology—the Forerunner of Astronomy (p. 612)

A. How is Astrology different from Astronomy?

B. How is the “zodiac” (Figure 21.C on p. 612) related to the ecliptic?

C. When astrological charts were first established, more than 3000 years ago, the sun was “in” Aries on the vernal equinox (around March 21st). Nowadays, on the vernal equinox, the sun is “in” Pisces². Why has this shift occurred?

Hint: This shift was caused by one of the motions of the earth you have just read about.

²By the way, the position of the sun on every other date has shifted over time as well. Your astrological “sign” is supposed to be determined by what constellation the sun appeared to be “in” on the day you were born. However, the astrological signs have not changed with the times (I was born on June 11. According to astrologers, I am a Gemini but the sun was in the center of Taurus when I was born). In light of these facts, what do you think about the validity of astrology? (You don't have to answer this question, just think about it).

- D. Explain the meaning of the expression “This is the dawning of the Age of Aquarius.”
Hint: This is also the “setting” of the “Age of Pisces.”

Calendars and Astronomy

- A. The Days of the Week: The reason we have 7-day weeks is because our ancestors noticed seven heavenly bodies “wandering” among the stars on the celestial sphere. These seven heavenly bodies were the sun, the moon and the planets Mercury, Venus, Mars, Jupiter and Saturn. The outermost planets (Neptune, Uranus and Pluto) also “wander” but the ancients didn't know about them because you need a telescope to see them (which is a very good thing—can you imagine having 8-day workweeks?). Note that, as seen from Earth, the stars do not appear to move relative to each other. Keep in mind, however, that they really are moving but they are so incredibly far away that we cannot detect that movement.

Name the heavenly body that each day of the week is named after (some days are easier to figure out in Spanish so I included the Spanish names too):

1. Sunday (Domingo in Spanish) _____
2. Monday (Lunes in Spanish) _____
3. Tuesday (Martes in Spanish) _____
4. Wednesday (Miércoles in Spanish) _____
5. Thursday (Jueves in Spanish) _____
6. Friday (Viernes in Spanish) _____
7. Saturday (Sábado in Spanish) _____

Homework Assignment #8: Causes of the Seasons

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Chapter 16 – The Atmosphere: Composition, Structure and Temperature

Earth-Sun Relationships (p. 455–460)

A. Earth's Motions

1. Rotation

- a. What is meant by rotation of the Earth?

- b. How long does it take the Earth to complete one rotation? _____

- c. At any moment, what % of Earth is experiencing daylight? _____

- d. What is the “circle of illumination?”

2. Revolution

- a. What is meant by revolution of the Earth?

- b. How long does it take the Earth to complete one revolution? _____

B. Seasons

1. Why is it colder in the winter than it is in the summer? Fully explain BOTH reasons.
 - a.

 - b.

2. How does the seasonal variation in the altitude of the noon sun affect the amount of energy received at the earth's surface? (in addition to reading the text, be sure to study Figure 16.10 on p. 456 and Figures 16.11 and 16.12 on p. 457)
 - a.

 - b.

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2. Seasonal Changes in the Location of the Vertical Rays of the Sun (In addition to reading the text, study Figure 16.13 and 16.14 on p. 458.)

- a. The Summer Solstice and the Tropic of Cancer (23.5° N. Latitude)

Draw a diagram showing the tilt of Earth's axis relative to the sun on June 21 or 22 (The Summer Solstice). Show which part of Earth experiences a vertical noon-day sun and why.

- b. The Winter Solstice and the Tropic of Capricorn (23.5° S Latitude)

Draw a diagram showing the tilt of Earth's axis relative to the sun on December 21 or 22 (The Winter Solstice). Show which part of Earth experiences a vertical noon-day sun and why.

c. The Autumnal and Vernal Equinoxes

Draw a diagram showing the tilt of Earth's axis relative to the sun on September 22 or 23 (The Autumnal Equinox) and March 21 or 22 (The Vernal Equinox). Show which part of Earth experiences a vertical noon-day sun and why.

3. Seasonal Changes in the Length of Daylight Versus Darkness (In addition to reading the text, study Table 16.1 on p. 459 and Figure 16.14 on p. 458.)

- a. The Summer Solstice and the Northern Hemisphere: Explain why there are more hours of daylight than darkness during the summer in the Northern Hemisphere. Draw a diagram to illustrate your answer.

Homework Assignment #8: Inquiry-Based Teaching

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Ready, Set Science!

Ready, Set, Science! Putting Research to Work in K-8 Science Classrooms, by Sarah Michaels, Andrew W. Shouse, and Heidi A. Schweingruber, under the National Research Council. Published by the National Academy Press in 2008.

Excerpts of this excellent book are posted on the course Blackboard Vista site. You can also purchase this book from http://www.nap.edu/catalog.php?record_id=11882.

Chapter 2: Four Strands of Science Learning (p. 17-21)

A. How do the authors of this book think about the scientific content and scientific processes?

B. For each of the four learning “strands” listed below, explain specifically what it involves.

Strand 1: Understanding Scientific Explanations

Strand 2: Generating Scientific Evidence

Strand 3: Reflecting on Scientific Knowledge

Strand 4: Participating Productively in Science

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B. Seeing Nature in New Ways (p. 41)

What is conceptual change?

C. Types of Conceptual Change (p. 42-43)

1. Elaborating on a pre-existing concept

Explain what it is:

Give an example of YOUR experience of this type of conceptual change in this class or in another science course.

2. Restructuring a Network of Concepts

Explain what it is:

Give an example of YOUR experience of this type of conceptual change in this class or in another science course.

3. Achieving New Levels of Explanation

Explain what it is:

Give an example of YOUR experience of this type of conceptual change in this class or in another science course.

D. Using Prior Knowledge to Make Sense of the World (p. 43-44)

How do the authors suggest that teachers handle children's "misconceptions?"

Chapter 5: Making Thinking Visible: Talk and Argument**A. Learning Through Talk and Argument (p. 88-89)**

1. List four reasons why talk is an important and integral part of learning science
 - a.
 - b.
 - c.
 - d.

2. What is the nature of scientific argumentation?
 - a. The object of the argument:

 - b. Norms of scientific argumentation:

 - c. Expected response to a persuasive claim that does not support one's position:

B. Encouraging Talk and Argument in the Classroom (p. 89-93)

1. How is discourse that encourages scientific talk argument different from the usual (Initiation-Response-Evaluation) pattern of discourse?

2. Write three specific question that would encourage scientific talk argument among the children when you teach them about the seasons or the phases of the moon.

3. In the table below, list the six productive classroom talk moves described in the reading and give examples of each that are different from the examples in the reading.

Talk Move	Example

4. The top of page 92 lists six reasons why productive classroom talk is very important. Choose one of these and give an example from your own learning.

5. Describe some ways that teachers can help children learn to conduct respectful scientific arguments instead of the confrontational competitive arguments they may be used to.

Inquiry and the National Science Education Standards

Inquiry and the National Science Education Standards: A Guide for Teaching and Learning, by the National Research Council. Published by the National Academy Press in 2000.

Excerpts of this excellent book are posted on the course Blackboard Vista site. You can also purchase this book from http://www.nap.edu/catalog.php?record_id=9596.

Images of Inquiry in 5-8 Classrooms (p. 48-57)

This passage in this book describes a teacher taught a unit on the phases of the moon and eclipses. Read this passage carefully, looking for the four strands of science learning described in the book *Ready, Set, Science!*

Analysis of 5-8 Image of Inquiry (p. 57-59)

This passage in this book analyzes the “Image of Inquiry” of the previous passage in terms of “Five Essential Features of Classroom Inquiry,” which are slightly different from the four strands of science learning.³ Write your own analysis of the “Image of Inquiry” unit on the moon, explicitly showing how this unit involved the “four strands of science learning.” You will probably need to attach an additional piece of paper.

³ In case you’re interested, the “Five Essential Features of Classroom Inquiry” are...

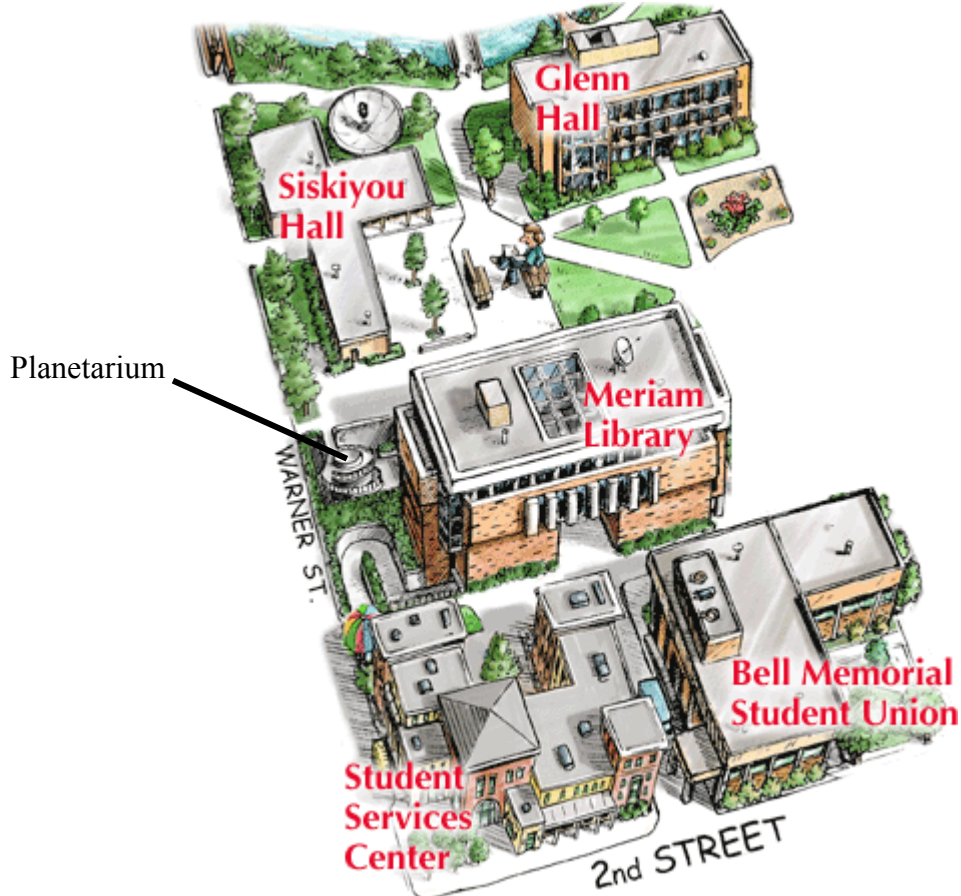
1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations

Planetarium Lab: Introduction to the Stars, Planets and Moon

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Map to the Planetarium

The planetarium is on Warner Street, across from the O'Connell building and next to the library.



Objectives

When you have completed this lab you should be able to

1. Point out the approximate locations of the meridian, zenith, horizon, north celestial pole and celestial equator in the sky. Be able to state the approximate altitude of any object in the sky.
2. Find and identify the five “circumpolar” constellations and the star Polaris (the North Star) in the night sky.
3. Describe the apparent nightly motion--i.e. apparent motion due to Earth's rotation--of the stars (as seen from Chico) and explain why the stars seem to move the way they do.
4. Use the *Star and Planet Locator* to find each planet and to find several major constellations.
5. Use the altitude (angle above the horizon) of Polaris to determine your latitude.

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Lab Activity #1: Language Used to Describe Locations in the Sky

Introduction: In order to be able to communicate with each other about what we're seeing in the sky, we define a sort of coordinate system that helps us describe where we are looking.

Activity: Watch and listen as your instructor defines and illustrates the terms listed below. Then illustrate the definition of each term by drawing on and labeling the diagram below.

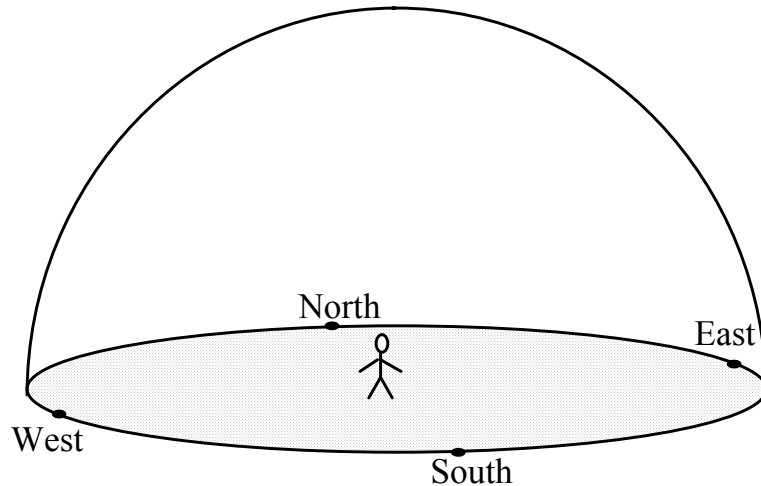
Things that are located in the same place in the sky, no matter where on Earth you are:

Celestial Meridian

Zenith

Horizon

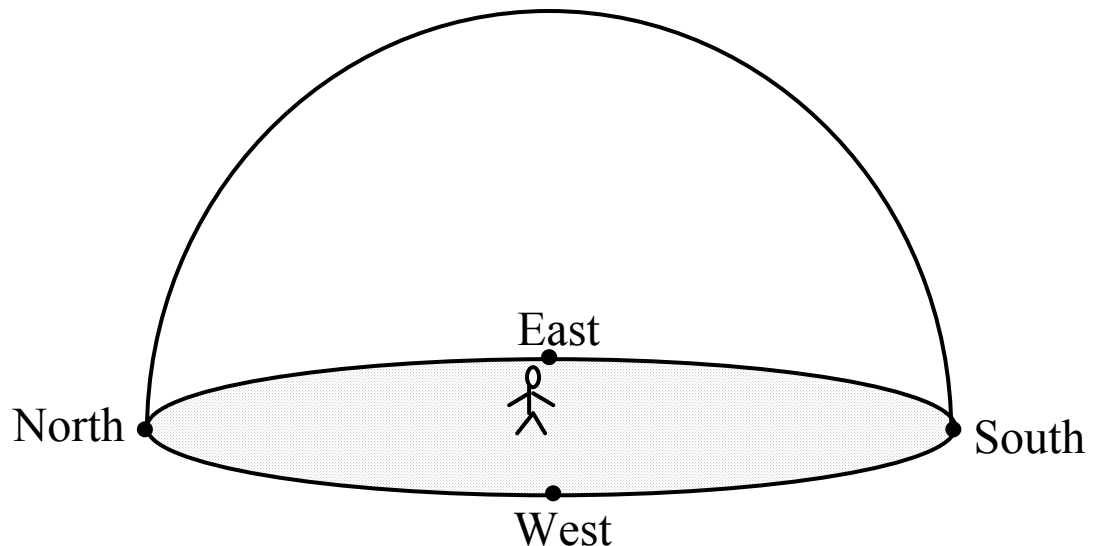
Altitude



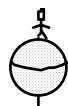
Things that are located in different places in the sky, depending on latitude

North Celestial Pole

Celestial Equator



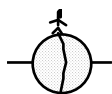
1. Describe a way to determine your latitude if you can measure the altitude of Polaris
2. Explain why Polaris is at different altitudes at different latitudes. To illustrate your answer, add to the diagrams below.



Person at the North Pole



Person in Chico (at 40° N. Latitude)



Person at the Equator

Lab Activity #2: The Circumpolar Constellations and the North Star

Introduction

One essential aspect of Astronomy is the identification of specific stars and groups of stars (i.e. constellations) in the sky--perhaps you once thought that was all there was to astronomy! We don't do this identification just for its own sake, but so that we can use the stars as landmarks to help us observe the changes in the night sky over time. We can then use those observations to better under-

stand the motions of Earth and the other objects in the solar system.

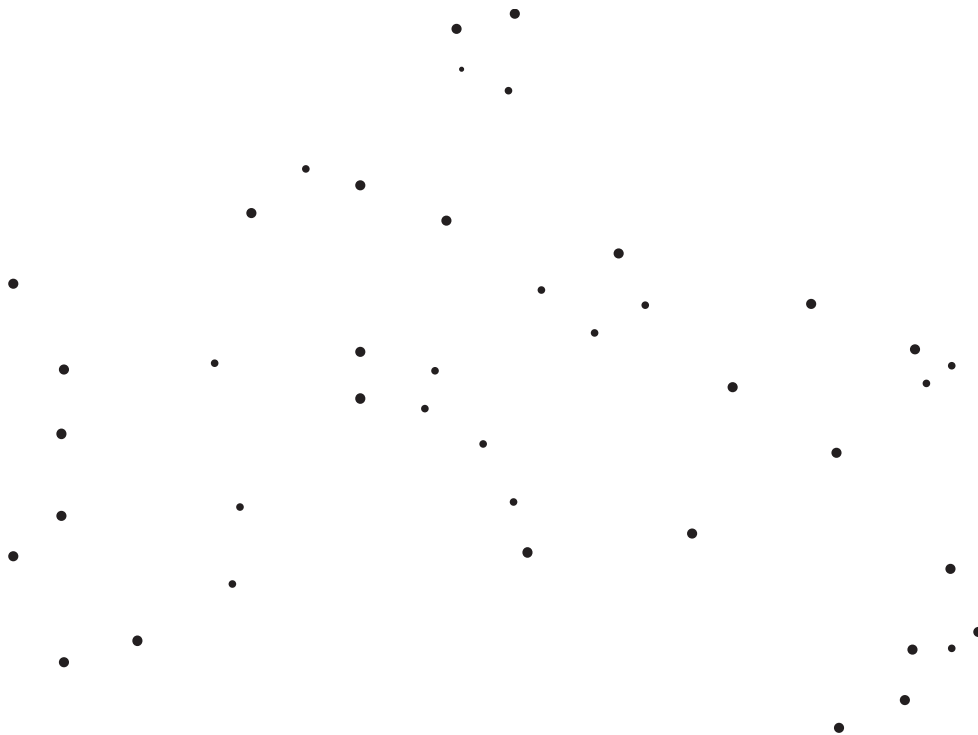
In the 48 states of the U.S., there are five constellations that are visible at all times of the night throughout the year. We call them the "circumpolar" constellations because they appear to go in circles around Polaris (the North Star). The circumpolar constellations are...

1. **Big Dipper:** not "officially" a constellation, actually just a part of the **Ursa Major** ("Big Bear") constellation. All you have to learn is the Big Dipper part of Ursa Major.
2. **Little Dipper:** informal term for the—entire—constellation **Ursa Minor** ("Little Bear").
3. **Draco** ("The Dragon").
4. **Cassiopeia**, an Ethiopian Queen and the mother of Andromeda in Greek mythology.
5. **Cepheus**, an Ethiopian King, husband of Cassiopeia in Greek mythology.

Polaris is the star on the end of the handle of the little dipper. It is also called the "North Star" because when you are facing it, you are looking directly north.

Activity: Find the five circumpolar constellations on the ceiling of the planetarium.

Question: Circle groups of stars shown in the diagram below to form the five circumpolar constellations. Label each constellation. Then label the star Polaris.



Lab Activity #3: The Apparent Nightly Motion of the Stars

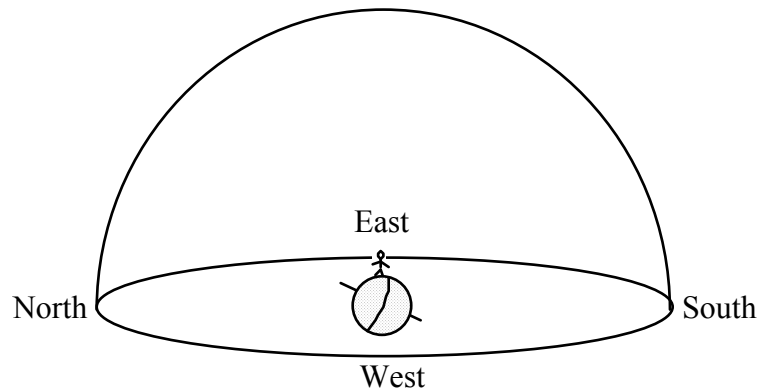
Introduction

When you look at the night sky, the stars do not appear to be moving. But if you look again an hour later, you will see that they are not in the same part of the sky as they were before. In the planetarium, we can greatly compress time and actually watch the stars move. This compression of time makes it easier to detect patterns in the apparent nightly movement of the stars.

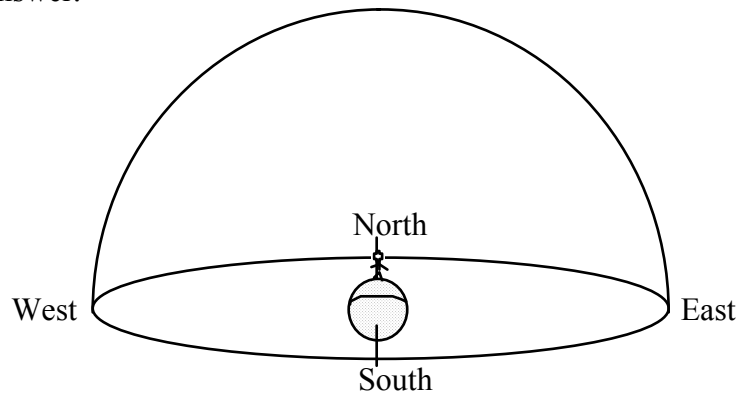
Activity: On the ceiling of the planetarium, observe the motions of the stars. Note especially their motion relative to Polaris (the North Star) and the Celestial Equator.

Questions

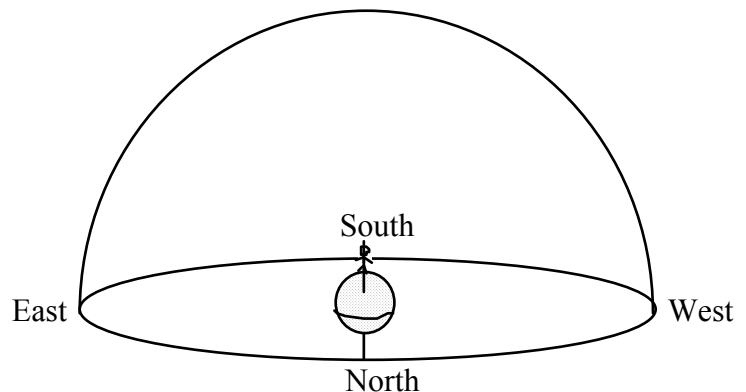
1. Why does the North Star stand still? Complete the diagram below to illustrate your answer.



2. Describe the apparent nightly motion of the stars with respect to Polaris. Complete the diagram below to illustrate your answer.



3. Describe/draw the apparent nightly motion of the stars with respect to the Celestial Equator.



Lab Activity #4: Using Your *Star and Planet Locator*

Introduction and Instructions

A *Star and Planet Locator* is a very handy device for locating the constellations. The one we have given you is designed to be used at any location with a latitude of 40° (the approximate latitude of Chico, Denver, Chicago and New York City).

Here is how you use the *Star and Planet Locator* to find the constellations:

1. Turn the circle until the current date and hour line up.
2. Hold the chart upside down, over your head, with North, South, East and West pointing in the proper directions.
3. The chart and the actual star positions should match (roughly—there is a lot of distortion).

Activity

1. Set the *Star and Planet Locator* for 8:00 p.m. tonight.
 - a. Use it to find the constellations named below:

Big Dipper	Cancer
Little Dipper	Gemini
Cepheus	Orion
Cassiopeia	Taurus
Draco	Pleiades (the seven sisters)
Leo	Canis Major (including the star Sirius)
 - b. Use the *Star and Planet Locator* to figure out where Jupiter will be at 8:00 tonight.
2. Set the *Star and Planet Locator* for 6:00 tomorrow morning.
 - a. Use it to find the constellations named below:

Big Dipper	Scorpius (including the star Antares)
Little Dipper	Sagittarius (also known as the teapot)
Cepheus	Libra
Cassiopeia	Hercules
Draco	Great Square
 - b. Use the *Star and Planet Locator* to figure out where Venus and Saturn will be at 6:00 tomorrow morning.
3. Set the *Star and Planet Locator* for 9 p.m. (i.e. 10 p.m. daylight savings time) for August 6.
 - a. Use it to find the constellations named below:

Big Dipper	Scorpius (including the star Antares)
Little Dipper	Sagittarius (also known as the teapot)
Cepheus	Libra
Cassiopeia	Hercules
Draco	Great Square
 - b. Use the *Star and Planet Locator* to figure out what planets will be visible on August 6, 2011 and where they will be.

Lab Activity on the Moon's Phases and Eclipses

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Objectives

When you have completed this lab you should be able to...

1. Demonstrate and illustrate how the relative positions of the sun, earth and moon cause the phases of the moon as seen from earth.
2. Given a drawing or photograph of the moon in any phase, be able to correctly name that phase and draw a diagram showing the relative positions of Earth, the moon and the sun for that phase.
3. Given a diagram showing any possible set of relative positions of Earth, the moon and the sun, determine the name of the moon phase and draw what the moon would look like in that phase.
4. State which way the moon revolves around Earth and describe a method for figuring this out.
5. Demonstrate why we always see the same side of the moon (the face side of the “man in the moon”)
6. Demonstrate what causes lunar and solar eclipses.
7. Explain why eclipses don't happen every month

Lab Activity #1: What do You Think Causes the Phases of the Moon?

Materials: Your notes and sketches of your recent observations of the moon

Activity: Study your notes and sketches; compare them with those of your group members. Draw a diagram, explaining any theories you have about why the moon goes through phases. Briefly explain your theory to your group members. At this point, don't evaluate your idea or anyone else's. Just let each person state his/her ideas.

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Lab Activity #2: Modeling the Phases of the Moon⁴

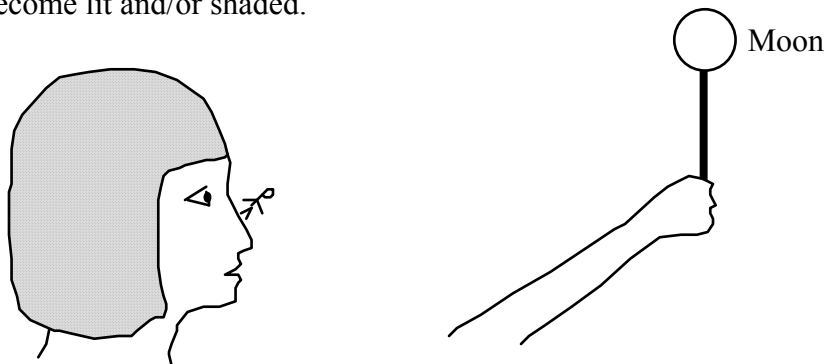
Materials: White polystyrene ball, 3 inches in diameter (to represent the moon)⁵

Pencil or other “stick”

Glowing light bulb (to represent the sun)

Activity:

1. Place the ball on the pencil.
2. Your instructor will turn on one light bulb and turn off all other lights in the room. The light bulb represents the sun, the white ball represents the moon and your head represents the earth. Imagine your nose as a giant mountain on the Earth's northern hemisphere with a tiny person standing on it (partially sideways), looking at the moon--see diagram below.
3. Hold the pencil with the white ball on it at arm's length in front of you and a little above your head. Slowly rotate your body, keeping the “moon” in front of you and watching as various parts of the white ball become lit and/or shaded.



Questions:

1. Draw diagrams showing the positions of the light bulb, your head, and the white ball (all as seen from the ceiling) for each of the following phases:
 - a. Full Moon (the part of the ball that you can see is fully lit):

⁴This lab activity was modified from Activity A-3 of the chapter entitled “Our Moon's Phases and Eclipses” in *The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook*: The Astronomical Society of the Pacific, San Francisco (1995).

⁵ A Styrofoam ball will not do; the ball must be opaque. We got our *Polystyrene* balls from Molecular Model Enterprises, 116 Swift St., P.O. Box 250, Edgerton, WI 53334, (608)884-9877, www.giantmolecule.com. We got 3 inch diameter balls for \$.45 each and 7/8 inch diameter balls for \$.12 each.

b. Quarter Moon (the part of the ball that you can see is half lit):

c. New Moon (the part of the ball that you can see is fully in shadow):

2. At any given time, what percentage of the model moon is actually lit? _____. Why?

If you are unsure of the answer to this question, watch the white ball as a partner repeats the activity described above.

Lab Activity #3: Determining which way the moon revolves around Earth

Materials: 3" diameter white polystyrene ball (to represent the moon) on a pencil
Glowing light bulb (to represent the sun)
Your notes and sketches of your recent observations of the moon

Introduction

We have all known, from a very young age, that the moon revolves around Earth and that it takes about a month to do so--hence the word *mo(o)nth*. But have you ever stopped to wonder which way the moon revolves around Earth? Does it revolve from east to west (clockwise when looking down on Earth's north pole) or from west to east (counterclockwise when looking down on Earth's north pole)? In this activity, we will figure out the answer to this question.

We will do this by using the time-honored scientific technique of “predicting” what we would observe IF a particular possible answer were correct. If we don't observe what we predicted, then we know that that particular possible answer is wrong. If we do, indeed, observe what we predicted, then that possible answer has a high probability of being correct.⁶ In this case, we have only two possible reasonable answers to our question, so the most reasonable right answer should be easy to determine by elimination.

Activity: For each possible answer to the question of which way the moon revolves around Earth (west-to-east or east-to-west), use the “moon on a stick” to “predict” which side of the moon (left or right) would be lit during the waxing⁷ phases and which side of the moon would be lit during the waning⁴ phases--as seen from the northern hemisphere.

Questions:

1. Complete this table	Side of the moon that would be lit during the waxing phases (right or left)	Side of the moon that would be lit during the waning phases (right or left)
If the Moon revolves from east to west (clockwise when looking down on Earth's north pole)		
If the moon revolves from west to east (counterclockwise when looking down on Earth's north pole)		

2. According to your notes from your recent observations of the moon,
 - a. Which side of the moon is actually lit during the waxing phase? _____
 - b. Which side of the moon is actually lit during the waning phase? _____
3. Conclusion: Which way does the moon actually revolve around Earth? _____

⁶ In science, we can only rule out wrong answers; we cannot prove right answers. We can be very very confident that a particular answer is correct but we can never be absolutely 100% sure—this limitation is an inherent aspect of the scientific method.

⁷ The waxing phases of the moon are when the lit portion of the moon is getting bigger from one night (or day) to the next; the waning phases are when the lit portion of the moon is getting smaller each night (or day).

Lab Activity #4: Synthesizing Your Understanding of the Phases of the Moon

Materials: 3" diameter white polystyrene ball (to represent the moon) on a pencil
 Glowing light bulb (to represent the sun)
 Partially completed “pop-up” moon diagram on card stock

Activity: Follow the instructions below to complete diagram on the card stock, turning it into a pop-up diagram. The circle in the center of the diagram represents the Earth and the eight small circles around it represent the moon at eight different positions on its orbit around Earth. Note that this pop-up diagram is not to scale. For reference, here are the earth and moon in the correct proportions with regard to both size and distance:



Instructions

1. On the diagram, write “To the sun” with an arrow pointed in the appropriate direction.
2. The partially-cut-out rectangles all around the diagram will show what the moon would look like to a person living near the equator who looks up through a skylight and sees the moon on eight different days (or nights) in the moon's cycle. Fold each rectangle up to represent a skylight above the person's head.
3. For each of the eight positions of the moon, darken⁸ the appropriate part of each circle in each “skylight” to show what the moon looks like to the person on Earth, directly below the moon. Draw each sketch in the box “above” the appropriate moon position (“Right side up” will be different for each moon-and-box pair; the Earth will be at the bottom for each).
4. “Above” each moon sketch, write the correct name for the phase of the moon (new, waxing crescent, waning crescent, 1st quarter, 3rd quarter, waxing gibbous, waning gibbous, full).⁹
5. “Below” each sketch of the moon, write the approximate day in the moon's 29-day cycle.

⁸Darken the part of the moon that is not visible; leave the “lit” portion of the moon white.

⁹ Definitions of the phases:

Full Moon	The moon is full when the side we see is 100% illuminated. A full moon looks like a perfect circle.
New Moon	The moon is new when the side we see is dark. We cannot see a new moon at all.
Crescent Moon	A crescent moon is shaped like a crescent; a smaller proportion of the moon is illuminated than is the case during a quarter moon.
Quarter Moon	The moon is called a quarter moon when it looks like a half circle.
Gibbous Moon	A gibbous moon is shaped like a lopsided football; a larger proportion of the moon is illuminated than is the case during a quarter moon.
Waxing Moon	The moon is waxing when the illuminated portion of the moon is getting a little bit bigger every day.
Waning Moon	The moon is waning when the illuminated portion of the moon is getting a little bit smaller every day.

Lab Activity #6: Why Do We Always See the Same Side of the Moon?

Introduction: Have you ever noticed that the pattern of light and dark spots (forming a “man” or “rabbit” in the moon) is the same all the time, no matter what phase the moon is in? This is because, from Earth, we can only see one side of the moon (See Figure 22.3 on p. 629 of the textbook or this cool(!) web site movie: <http://antwrp.gsfc.nasa.gov/apod/ap991108.html> or this very sharp still image: http://antwrp.gsfc.nasa.gov/apod/image/0001/fm1222_gendler_big.jpg). The other side of the moon is always turned away from us--to see a photograph of the far side of the moon, go to the following web site: <http://antwrp.gsfc.nasa.gov/apod/ap981008.html>.

Materials: Two people
Photographs of the “near” and “far” sides of the moon

Activity: Examine the photographs of the “near” and “far” sides of the moon; note how unfamiliar the “far” side of the moon looks. Choose one person to model the moon and one to model Earth. Have both people stand up and then have the “moon” revolve around “Earth” so that “Earth ” can only see the “moon's” face, never the back of the “moon's” head.

Questions:

1. For each 360° revolution of the “moon” around “Earth,” how many times did the “moon” rotate (spin about its axis) 360° ? Explain.
2. What would happen if the “moon” did not rotate (e.g. always faced the front of the classroom) as it revolved around “Earth?”
3. Does the real moon rotate? If so, how long does it take to complete one 360° rotation? Explain the reasoning behind your answer.

Lab Activity #7: What Causes Solar and Lunar Eclipses?¹⁰

Materials: White polystyrene ball, 3 inches in diameter (to represent the moon)
Pencil or other “stick”
Glowing light bulb (to represent the sun)

Activity: As in activity #2, hold the ball out in front of you, but hold it level with your eye. Face the light bulb and hold the ball so that it blocks the light; it may help to close one eye.

Question: 1. What kind of eclipse are you modeling?¹¹ _____

More Activity: Now face away from the light bulb and hold the ball so that the shadow of your head covers the ball.

Question: 2. What kind of eclipse are you modeling? _____

More Questions:

3. What phase is the moon in during a lunar eclipse? _____

4. What phase is the moon in during a solar eclipse? _____

5. Describe what causes a lunar eclipse. Draw a diagram to illustrate your answer.

6. Describe what causes a solar eclipse. Draw a diagram to illustrate your answer.

¹⁰This lab activity was modified from Activity A-4 of the chapter entitled “Our Moon's Phases and Eclipses” in *The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook*: The Astronomical Society of the Pacific, San Francisco (1995).

¹¹ A solar eclipse happens during the day, when the sun is not visible at a time when it should be. A lunar eclipse happens at night, when the moon is not visible (or is VERY faint) when it should be very bright.

Lab Activity #8: Why Don't We Have Solar and Lunar Eclipses Every Month?

Introduction: As you know, in any given place, a total lunar eclipse occurs less than once a year. And a total solar eclipse is a once-in-a-lifetime phenomenon (I've never seen one). In this activity, we will figure out why. We will do this by making a true-to-scale model of the moon and Earth (the sun will NOT be to scale in this model).

Materials: 3" diameter white polystyrene ball (to represent the EARTH this time) on a pencil
7/8" diameter white polystyrene ball (to represent the MOON)
paperclip
Overhead Projector (to represent the sun)

Activity: Lunar Eclipse

1. "Unbend" one fold of the paperclip and insert the end into the 7/8" diameter polystyrene ball, providing a "stick" for holding up the ball.
2. As a group, go to the room adjacent to the lab room where the overhead projector is set up, bringing one model moon and one model Earth along. With one person holding the moon and one person holding the Earth, place the moon and Earth exactly 8 feet apart¹² in a line with the projector so as to model a lunar eclipse true to scale.¹³
3. Move the moon or Earth slightly up or down, noticing how precisely the moon and Earth must line up in order for a lunar eclipse to occur.

Activity: Lunar Eclipse

1. Put the small ball on the paperclip.
2. Have one person hold the moon and one person hold the Earth. Place the moon and Earth exactly 8 feet apart in a line with the projector.¹⁴
3. Move the moon and Earth until you cause a solar eclipse. Do the same for a lunar eclipse.

Questions:

1. When the sun, Earth and the moon line up, what happens if they don't line up perfectly? Why?

¹² Note: the tiles in the room are exactly one foot square.

¹³ If we were to model the sun correctly to scale with this model Earth and moon, the sun would be 29 feet in diameter and located 1.2 miles away, as far from here as is the corner of 9th St. and Main St.

¹⁴ If we were to model the sun correctly to scale with this model Earth and moon, the sun would be 29 feet in diameter and located 1.2 miles away, as far from here as is the corner of 9th St. and Main St.

Lab Activity on The Solar System and Why it is Warmer at the Equator than it is at the Poles

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Objectives

When you have completed this lab you should be able to

1. visualize the proportions of the solar system--the sizes of objects and distances between them.
2. clearly and fully explain why it is warmer at the equator than it is at the poles.

Lab Activity #1: Scale Model of the Solar System

In this scale model, 1 mm in the model = 2000 km in real life.

Object	Diameter	Diameter for Scale Model	Average Distance from Sun	Distance for Scale Model
Sun	1,400,000 km	700 mm	—	—
Mercury	4,900 km	2.45 mm	58,000,000 km	29 m
Venus	12,100 km	6.0 mm	108,000,000 km	54 m
Earth	12,750 km	6.4 mm	150,000,000 km	75 m
Earth's moon	3,500 km	1.8 mm	385,000 km from Earth	0.19 m from Earth
Mars	6,800 km	3.4 mm	228,000,000 km	114 m
Jupiter	142,600 km	71.3 mm	778,000,000 km	389 m (\approx 1/4 mile)
Saturn	120,500 km	60.3 mm	1,427,000,000 km	714 m (\approx 1/2 mile)
Uranus	51,100 km	25.5 mm	2,869,000,000 km	1435 m (\approx 0.9 mile)
Neptune	49,500 km	24.8 mm	4,497,000,000 km	2249 m (\approx 1.4 miles)
Proxima Centauri (nearest star, a companion of Alpha Centauri)	200,000 km	100 mm	4.24 light years (40,300,000,000,000 km)	20,140 km (12,590 miles)

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Materials: 11 spherical objects of various sizes and colors

Ruler (with cm on it)

Tape measure (with meters on it)

Activity:

- a. Choose an appropriate spherical object to represent each object in the solar system.

Real Object	Model Object
Sun	Large yellow exercise ball
Mercury	
Venus	
Earth	
Earth's moon	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Proxima Centauri	

- b. Go outside to a large open flat space and make a scale model of the solar system as far out as Mars. Put the “sun” on its stand on one side of the space. As a class, walk from the “sun” to the scale model location of each planet, leaving a ring stand on the ground to mark the location of each planet so that you can see it from the other planets. Note the apparent size of the “sun” from Earth--it should look about as large as the real sun looks in the sky.

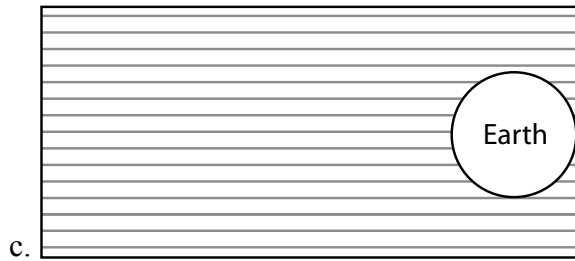
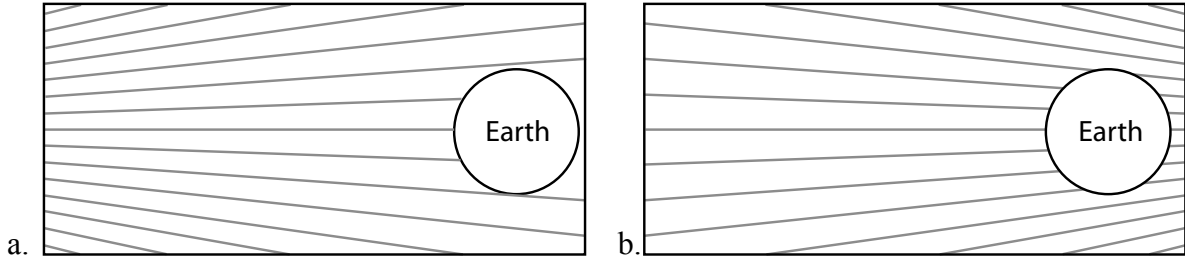
For those who might wish to make a model of the entire solar system at this scale, here are the locations of the planets beyond Mars (and the nearest star) on this scale model.

Planet	Scale Model Location
Jupiter	Corner of Broadway and 4th St.
Saturn	Corner of Broadway and 7th St.
Uranus	Corner of Park and 13th St.
Neptune	Corner of Park and 21st St.
Proxima Centauri	Half way around the world.

WARNING! This model can lead to misconceptions if you're not careful. In reality, the planets are never in a straight line like this; they all orbit the sun at different speeds and so are scattered in all directions around the sun.

Questions (to be answered after returning to the lab room): As you answer these questions, think about the proportions of the solar system and the implications of those proportions.

1. For each diagram below, the sun is at some distance to the left. Which diagram more accurately portrays the pattern of sun rays hitting Earth? Why?



2. On Earth, is the equator closer to the sun than are the poles? _____

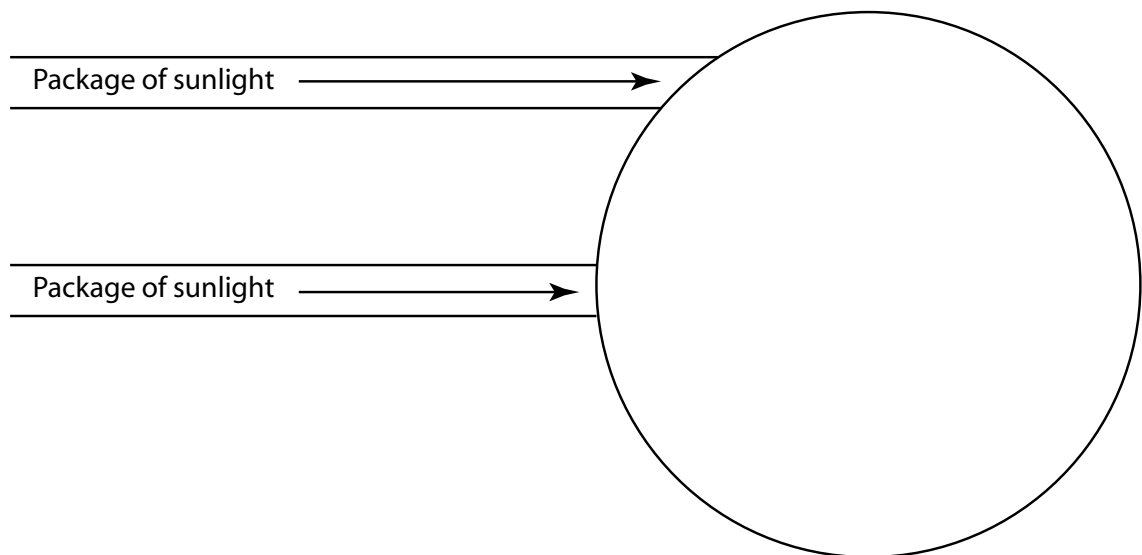
If so, is this difference significant when compared to the total distance between Earth and the sun? Explain.

More Activity: Use the overhead projector to project the image of the two squares onto a large globe. Move the cardboard as needed so that one square is projected on the equator and one square is projected near the North Pole. The overhead projector represents the sun. The globe represents the Earth (now realistically represented as a sphere). Note the sizes and the brightness of the squares projected onto the globe.

4. Are both squares projected onto the globe the same size and brightness or are they different? Draw a diagram to illustrate your answer.

5. Is the intensity of sunlight the same at all latitudes on Earth? Explain. Draw diagrams to illustrate your answer.

6. Why did the squares look different when they were projected on a globe than they looked when they were projected onto a flat piece of poster board? Hint: Think about the diagram on the next page and use the wood dowel to model packages of sunlight striking different parts of the globe. Be sure to hold the piece of wood so that it is horizontal.

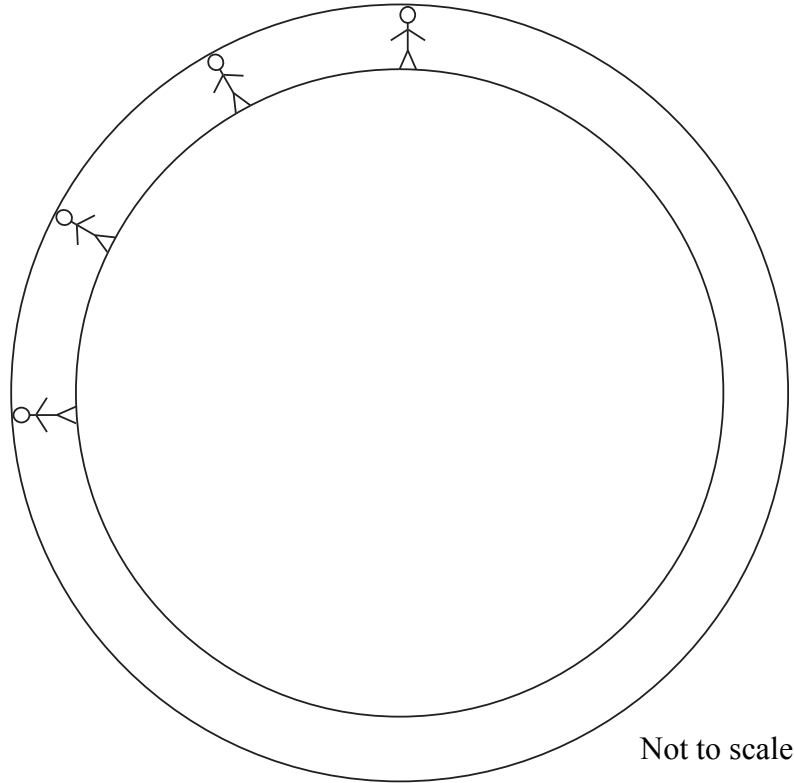


7. Imagine tiny people standing at various latitudes on your globe. Would all of these people see a **noonday** sun directly overhead, or would there be some variation? Explain. Draw a diagram to illustrate your answer.

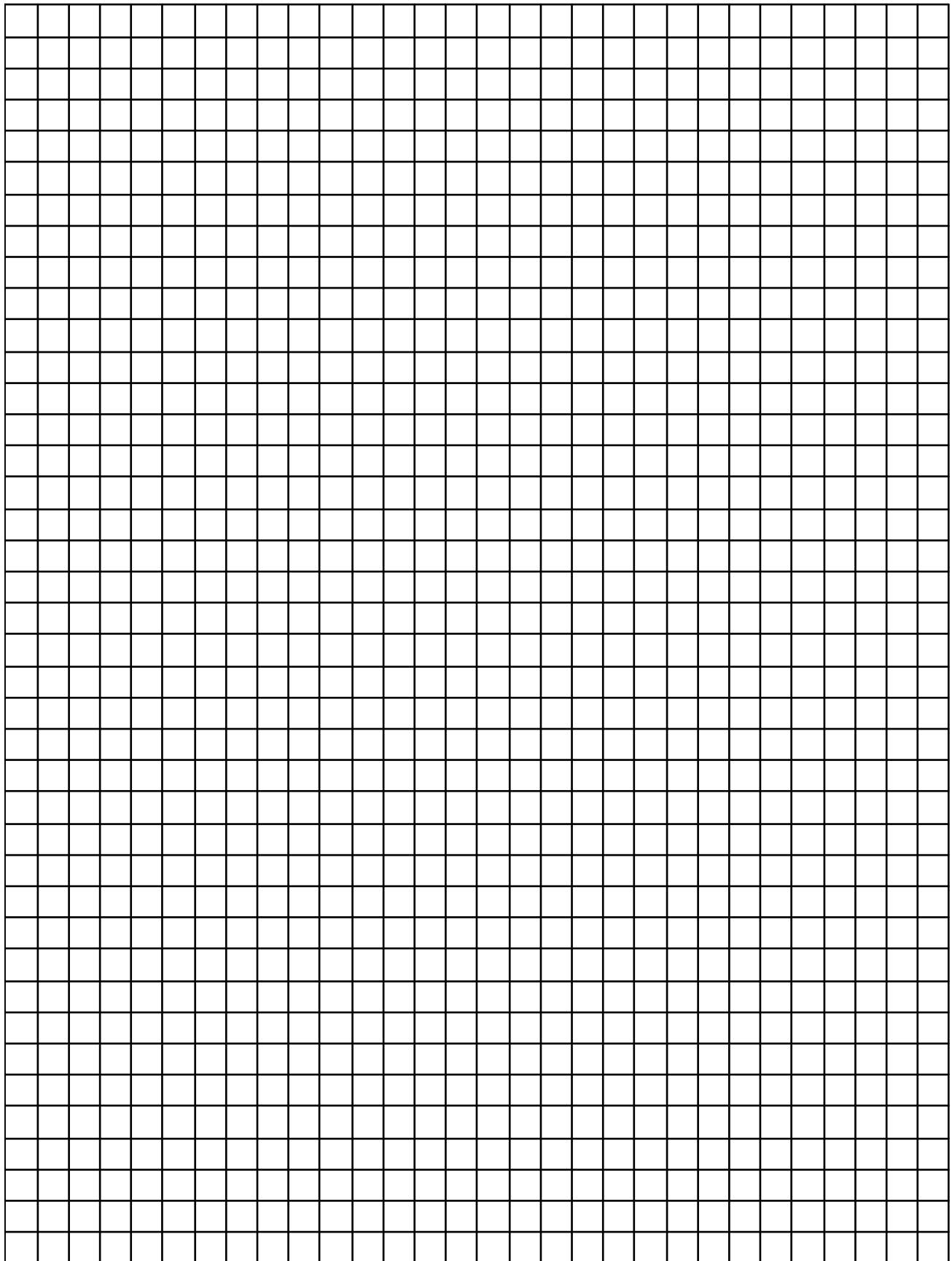
More Activity: In order to better understand why the intensity of the light hitting various parts of Earth varies, we will explore the relationship between the angle of incident light and the intensity of the light.

1. Shine the flashlight straight down on your grid paper (back of this lab), holding the flashlight 2-3 inches above the paper. On the paper, outline the bright spot.
 2. From the same height, shine the flashlight at an angle to your grid paper. Again, outline the bright spot.
8. When light strikes a surface at a high angle of incidence (near 90°), the intensity of the light is stronger / weaker (circle the correct answer) than it is when the same light strikes a surface at a small angle of incidence (near 0°).
 9. Clearly and fully explain why the angle at which light strikes a surface affects the intensity of the light energy felt by that surface.

10. There's one more piece to the puzzle of why the equator is warmer than the poles. This piece of the puzzle involves the atmosphere. The atmosphere absorbs, reflects and scatters sunlight; the more atmosphere a ray of sunlight must go through to get to the ground, the less energy will make it all the way to the ground. Imagine an atmosphere of uniform thickness covering your model Earth. Would sunlight have to go through the same thickness of atmosphere to reach the equator as it would to reach the poles? Explain. Complete the diagram below to illustrate your answer (Note: Your answer to Question #1 of Activity #1 may be helpful).



11. Use all the concepts you have learned so far to fully explain why the equator is warmer than the poles.



Lab Activity on the Causes of the Seasons

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Objectives

When you have completed this lab you should be able to show how the tilt of Earth's axis and Earth's revolution around the sun causes seasonal variations in...

- Temperature
- Day length
- Height of the noonday sun

Lab Activity #1: Eliciting Your Understanding of the Causes of the Seasons

Introduction: We have just figured out why the equator is warmer than the poles. But, as you well know, our weather is not the same all year round. It is warmer in the summer than in the winter. The purpose of this activity is for you to realize exactly what you know (or at least what you think) about the causes of the seasons.

Materials: glowing light bulb (to represent the sun)
Polystyrene ball with a stick through the center of it (the stick represents Earth's axis)

Activity: Within your group, take turns expressing your ideas about the causes of the seasons. Use the lamp and small globe as props for your explanations. Don't try to be "correct;" try to express what you REALLY believe. One piece of IMPORTANT information: Earth and all the other planets orbit the sun in a flat plane; Earth is never significantly "above" or "below" the level of the sun. Keep this in mind when you demonstrate your ideas; i.e. as you demonstrate Earth's orbit, keep the model Earth at the same height as the model sun (the light bulb).

Questions: Try to reach consensus within your group and construct a new group model that explains Earth's seasons. Describe and illustrate this model below.

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Lab Activity #2: Testing, Refining and Applying Your Model of the Causes of the Seasons

Introduction: Part of the scientific process is to constantly test models to see if they can account for all observations. If they do not, we modify them. During this activity, you will be testing your model and modifying it (or starting over) as necessary in order to account for all the observations listed below.

Materials: Glowing light bulb (to represent the sun)
Polystyrene ball with a stick through it (the stick represents Earth's axis)

Activity: For each observation below, use the materials above to explain the cause of each observation. If your model is not compatible with a particular observation, refine, add to or change your model as necessary.

- A. **The Shape of Earth's Orbital Path:** The table in the “Lab Activity on the Solar System and Why It’s Warmer at the Equator than it is at the Poles” states the **average** distance of Earth from the sun (150,000,000 km). The actual distance varies during the year because Earth's orbit isn't perfectly circular¹⁵. The table below provides Earth's average distance from the sun during selected months of the year.¹⁶

Month	Average Earth-Sun Distance ¹⁷
January	147,000,000 km
March	149,000,000 km
June	153,000,000 km
July	153,000,000 km
September	150,000,000 km
December	148,000,000 km

- When is Earth closest to the sun? _____
When is Earth farthest from the sun? _____
- Can the distance between Earth and the sun account for the seasons? _____
Explain the reasoning behind your answer.

¹⁵**Note:** Earth's orbit around the sun is nearly a perfect circle; it is off by only 4%. Astronomers have calculated the resulting difference in incoming solar radiation: it is only 7%.

¹⁶For those who are curious, astronomers calculate these distances from the size of the sun as seen from Earth (objects look bigger when they're closer and smaller when they're farther away).

¹⁷**Source:** Fraknoi, A. (ed.), 1995, *The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook*: San Francisco, Astronomical Society of the Pacific. This is an EXCELLENT resource for teaching astronomy.

-
- B. The North Star Stands Still: At any particular latitude of the northern hemisphere, the North Star is always in the same place in the sky (always straight north, always the same distance from the horizon); no matter what time of day you look or what day of the year it is.

Does your current working model “predict” this result? If so, use the polystyrene ball and the light to show how your model explains why the North Star “stands still.” If your group model does not predict this result, construct a new model that does and describe how this new model can explain why the North Star stands still.

- C. Timing of the Seasons in the Northern and Southern Hemispheres: When it is summer in California (northern hemisphere), it is winter in Argentina (southern hemisphere) and visa versa.

Does your current working model “predict” this result? If so, use the polystyrene ball and the light to show how your model explains why summer and winter are reversed in the northern and southern hemispheres. If your group model does not predict this result, construct a new model that does and describe how this new model can explain why the seasons are reversed in the northern and southern hemispheres.

D. Lengths of Days and Nights

- At the equator, days and nights each last exactly 12 hours, all year round.
- Everywhere other than the equator, days are longer in summer than in winter. The longest day for us in the northern hemisphere is on the summer solstice (around June 21); the longest day for the southern hemisphere is on the winter solstice (around December 21). For example, at 40° N Latitude (e.g. San Francisco, Denver, New York), the days are almost 15 hours long on June 21, but they are less than 9 ½ hours long on December 21. The closer you get to the poles, the more pronounced this difference is. For example, in Anchorage, Alaska (61° N Latitude), the days are 18 ½ hours long on June 21, but they are only 5 ½ hours long on December 21.
- At the North Pole, it is dark from the autumnal equinox (around September 21) through the vernal equinox (around March 21) and light from the vernal equinox to the autumnal equinox. When it is light at the North Pole, it is dark at the South Pole and visa versa.
- At all locations on Earth other than the poles, there are exactly 12 hours between sunrise and sunset on the dates of the equinoxes.

Activity: Draw a dot on the polystyrene ball to represent your town; be sure to place it at the appropriate latitude (consult a globe as necessary). Place the polystyrene ball in the appropriate positions relative to the light to represent the solstices and equinoxes. Note that you can easily see the *circle of illumination* (the line between day and night) on the ball. At each position, spin the ball on its axis to model Earth's daily rotation. Complete the table below.

Season	Proportion of each 24-hour day that your town spends in the light vs. the dark		Drawing that shows... <ul style="list-style-type: none"> • The Earth, complete with axis and equator • Your town's location and the path it follows as Earth rotates • The circle of illumination • The direction to the sun
Winter Solstice	% of time in the light		
	% of time in the dark		
Spring Equinox	% of time in the light		
	% of time in the dark		
Summer Solstice	% of time in the light		
	% of time in the dark		
Fall Equinox	% of time in the light		
	% of time in the dark		

Question: Can the change in the # of hours of daylight over the course of a year **help** (it doesn't have to be the only factor) explain the differences in temperature between summer and winter? If so, explain how. If not, explain why not.

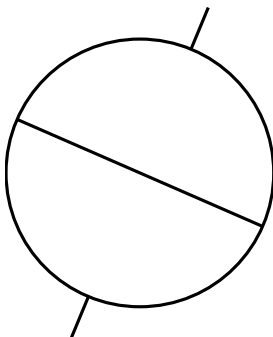
E. Attributes of the Tropics of Cancer and Capricorn:

- At 23.5° North latitude (the Tropic of Cancer), the sun is directly overhead at noon on the summer solstice (around June 21).
- At 23.5° South latitude (the Tropic of Capricorn), the sun is directly overhead at noon on the winter solstice (around December 21).

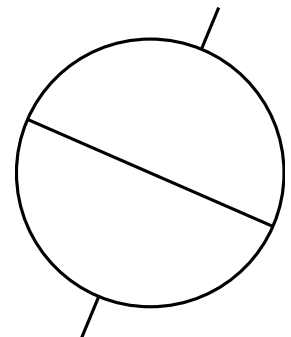
Activity: Draw two circles on your polystyrene ball in the appropriate positions to represent the Tropic of Cancer and the Tropic of Capricorn. Place the polystyrene ball in the appropriate positions relative to the light to represent the summer and winter solstices.

Complete the diagram below, adding

- The sun and its rays
- The Tropics of Cancer and Capricorn
- The angle between the sun's rays and the ground at each of the Tropics



Date: _____



Date: _____

F. Attributes of the Arctic and Antarctic Circles:

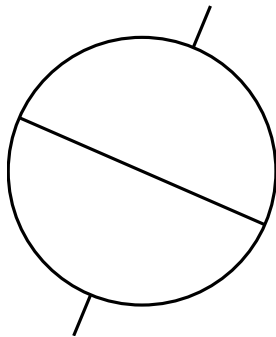
- At 66.5° North latitude (the Arctic Circle), the sun never sets on the summer solstice (around June 21); on all other days, the sun does go down at least for a little while. Everywhere north of the Arctic Circle, there are even more days when the sun never sets in the summer (the further north you go, the more days there are with 24 hours of light--“Midnight Sun”).
- At 66.5° North latitude (the Arctic Circle), the sun never rises on the winter solstice (around December 21); on all other days, the sun does make an appearance. Everywhere north of the Arctic Circle, there are even more winter days when the sun never rises (the further north you go, the more days there are with 24 hours of darkness).
- At 66.5° South latitude (the Antarctic Circle), the situation is similar but reversed (substitute June 21 for Dec. 21 and visa versa).

Activity: Draw two circles on your polystyrene ball in the appropriate positions to represent the Arctic and Antarctic circles. Place the polystyrene ball in the appropriate positions relative to the light to represent the summer and winter solstices. Rotate the ball on its axis to represent Earth's rotation.

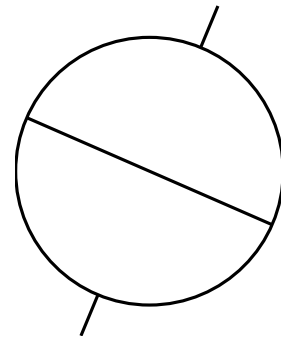
Question: What is special about the Arctic and Antarctic Circles (at the solstices) that can explain the above observations?

Complete the diagram below, adding

- The sun and its rays
- The circle of illumination
- The Arctic and Antarctic Circles



Date: _____



Date: _____

Lab Activity on Motion of Celestial Objects Across the Sky

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Objectives

When you have completed this lab you should be able to use the cardboard *Solar Motion* model and the Celestial Globe to figure out the apparent path of the sun across the sky for any date of the year at any location in the northern hemisphere. Specifically, you should be able to...

1. Explain what makes the sun, moon and stars rise and set.
2. Describe the apparent annual motion--i.e. apparent motion due to Earth's revolution--of the sun across the constellations and explain why it seems to move the way it does.
3. Describe where (i.e. in the NE, E, SE, S, SW, W, NW) the sun rises and sets in various places on various dates and explain why the sun doesn't always rise exactly in the east or set exactly in the west.
4. Determine the approximate altitude of the noonday sun in various places on various dates and explain why that angle changes with latitude and season.

Lab Activity #1: Modeling the Apparent Motion of the Sun, Moon and Planets Through the Constellations of the Zodiac

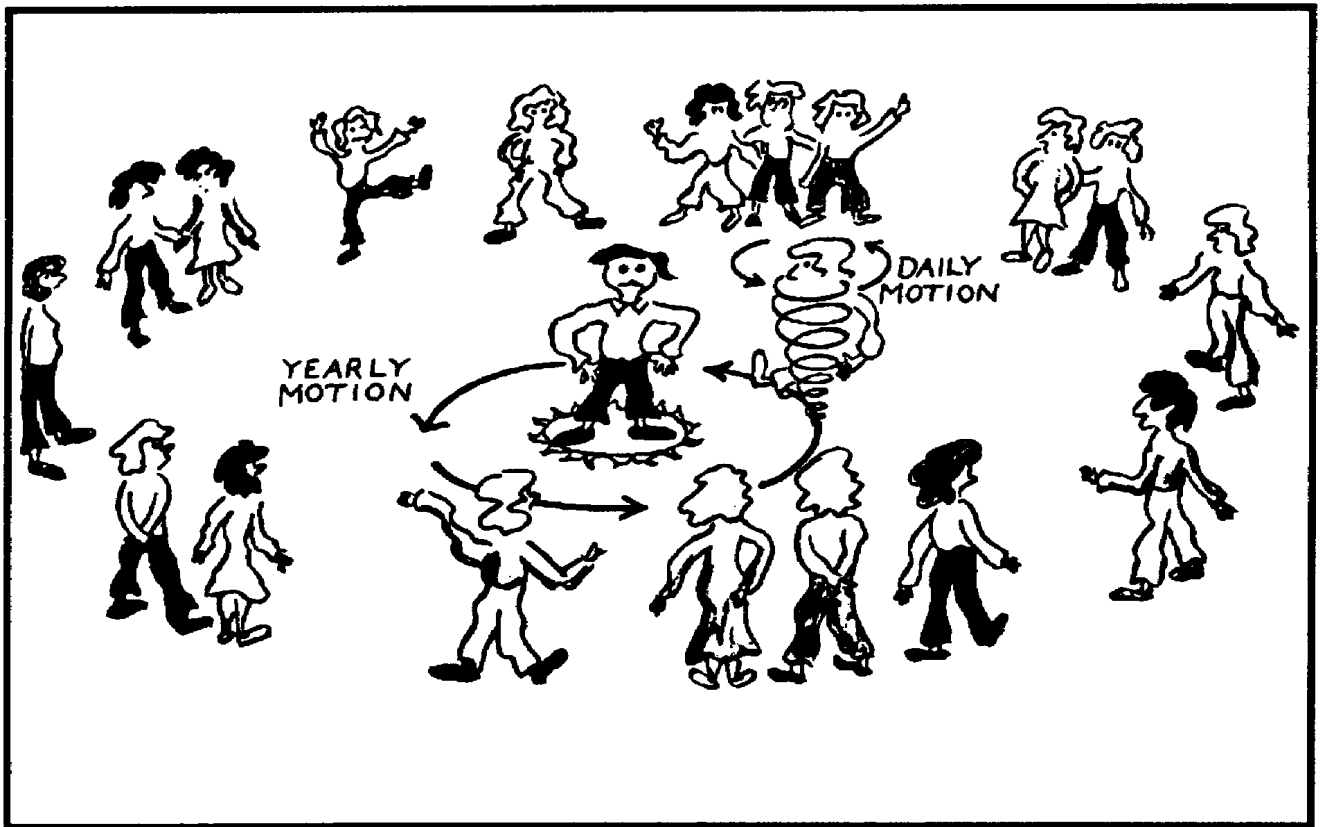


Illustration of the First Activity

(Source: p. 30 of the chapter on Planets in *The Universe at Your Fingertips: an Astronomy Activity and Resource Notebook*: Astronomical Society of the Pacific, 1995).

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Materials: SC001 Charts of the constellations (you may keep one)
12 sheets of paper labeled with the different Zodiac constellations

Activities (Do these activities as a whole class)

1. **Sun signs:** One person represents the earth, another represents the sun and everyone else represents stars of the Zodiac constellations. Form a large circle around the room, with the “sun” in the center and the “earth” next to the sun. Space the various “stars” around the circle in twelve groups, one for each sign of the Zodiac; be sure to place them in the proper order (use the SC001 chart to guide you) and have each group hold a sign for their particular constellation. Everyone stays in place except the “earth.” Have the “earth” orbit around the “sun” (be sure to orbit in the proper directions) and note how, from the view of Earth, the sun seems to move through the constellations.
2. **Moon signs:** A third person enters the center of the circle to represent the moon. Have the moon revolve around Earth. Note that, from the view of Earth, the moon seems to move through the constellations.
3. **Retrograde Motion of the Planets:** Usually, the other planets move through the constellations in the same direction that the moon and sun do (from right to left across the sky), but sometimes they seem to move backwards for awhile. This composite NASA photo shows the change in location for Mars over several months.



Model this retrograde motion using three people representing the sun, Earth, and another planet.

Questions

1. The SC001 chart shows the location of the sun (as seen from Earth) for each day of the year. Which constellation was the sun “in” on your birthday?
 2. Your astrological sun “sign” is supposed to be the constellation that the sun was “in” on your birthday. Locate the constellation that corresponds to the sun “sign” you have always considered yourself to be. Was the sun really “in” that constellation on your birthday?
-

What do you suppose has changed since the “sun signs” were established about 3000 years ago? Hint: the answer is in the reading for Homework #6.

Lab Activity #2: The Daily Path of the Sun Across the Sky

Important Information

- On the equinoxes ONLY, the sun rises exactly in the east and sets exactly in the west.
- In any 24-hour period, the sun always appears to travel parallel to the Celestial Equator
- On the equinoxes (March 21 and September 21),
the angle of the noonday sun = $90^\circ - (\text{your latitude})$.
- On the summer solstice (June 21), the angle of the noonday sun = $90^\circ - (\text{your latitude}) + 23.5^\circ$.
- On the winter solstice (December 21), the angle of the noonday sun = $90^\circ - (\text{your latitude}) - 23.5^\circ$

At any given location on Earth, the apparent daily path of the sun across the sky varies systematically with the seasons. This variation is due to the tilt of the Earth. Once you understand how this works, you can actually predict where the sun will rise and set on a particular date and how high the sun will be at noon. In this activity, you will use the model celestial sphere and a simple *solar motion* model to observe where the sun rises and sets and the height of the sun at noon at various times of the year in various places.

Materials: Solar motion demonstrator¹⁸ (you may keep one)
Clear plastic hemisphere
Water-soluble overhead transparency pen

Activity:

1. For Chico (latitude 40°N), determine the apparent path of the sun across the sky on the equinoxes and solstices using the *Solar Motion* model.
2. Complete the appropriate boxes in the table on the next page.

Note on Locations of Sunrise and Sunset: Whenever the locations of sunrise and sunset are not exactly east and west, you do not have to determine an exact location; NW, NE, SW, or SE is good enough.

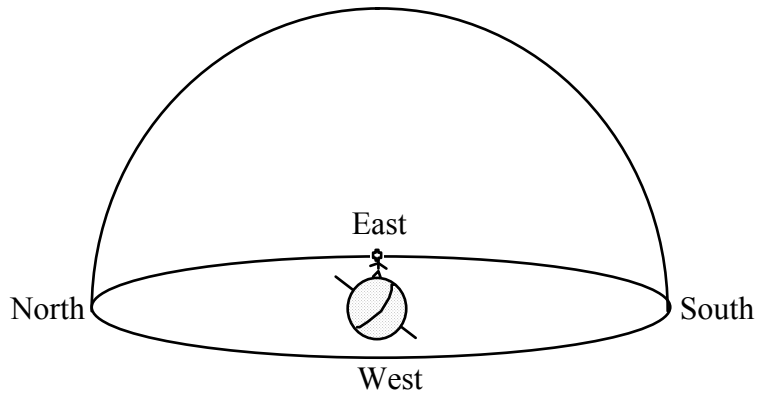
Note on Number of Hours of Daylight: Whenever the # of hours of daylight is not exactly 0, 12 or 24 yours you may simply state “Less than 12 hours” or “More than 12 hours.”

3. Draw the path of the sun at the solstices and equinoxes on the clear plastic hemisphere.
4. On the hemisphere diagram provided on the next page, draw the path of the sun at the solstices and equinoxes. In addition, draw the North Celestial Pole and the Celestial Equator on the hemisphere diagram.

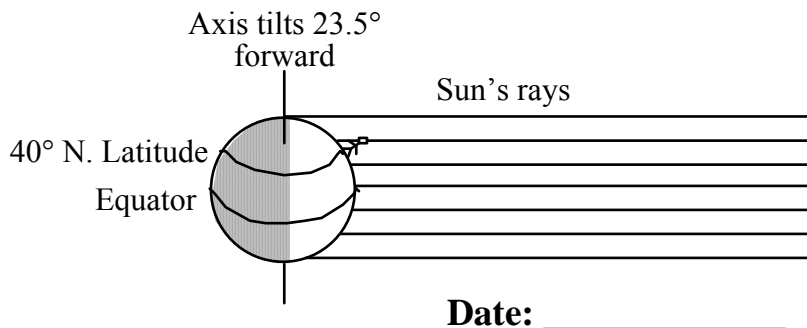
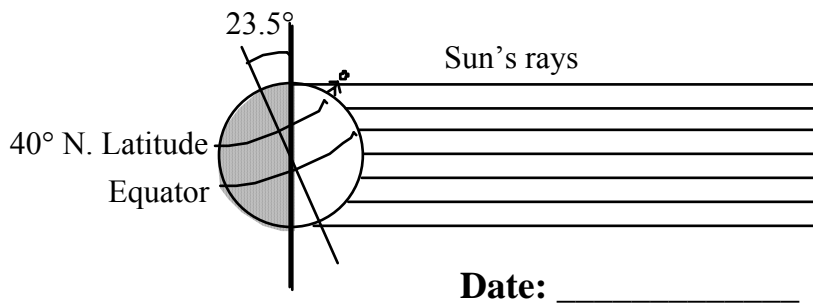
¹⁸ Available from the Astronomical Society of the Pacific at www.astrosociety.org.

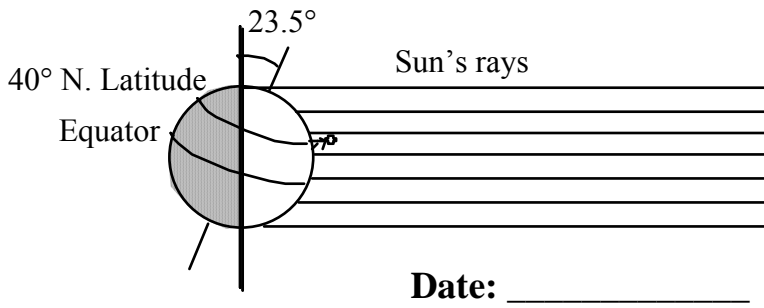
At Chico (40° N. Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise			
Altitude (angle to horizon) of sun at noon			
Location of sunset			
# of hours of daylight			

Draw the North Star, the Celestial Equator and all three paths of the sun.



5. Using what you learned in the lab on seasons, explain why the noon-day sun is at different altitudes at different times of the year. To illustrate your answer, add to the diagrams below.

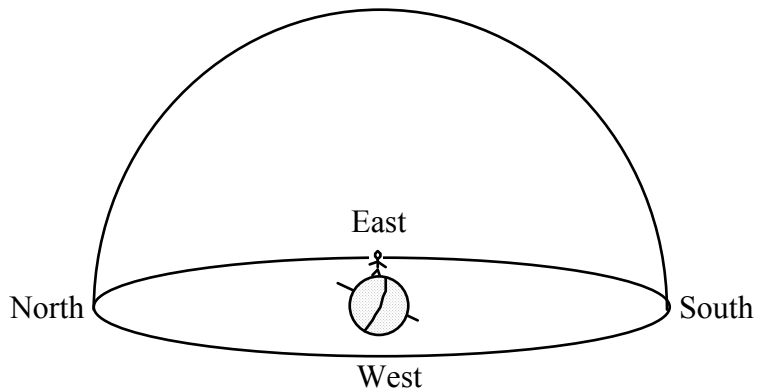




6. Repeat steps 1 through 4 for the Tropic of Cancer, Equator, and North Pole, completing the tables and diagrams below.

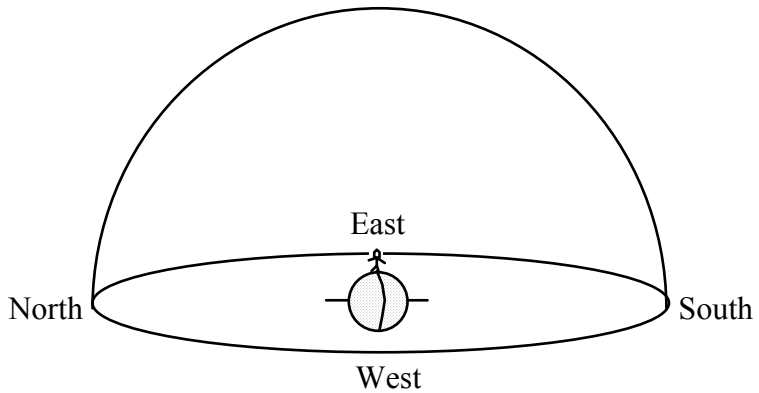
At the Tropic of Cancer (23.5° N. Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise			
Altitude (angle to horizon) of sun at noon			
Location of sunset			
# of hours of daylight			

Draw the North Star, the Celestial Equator, and all three paths of the sun.



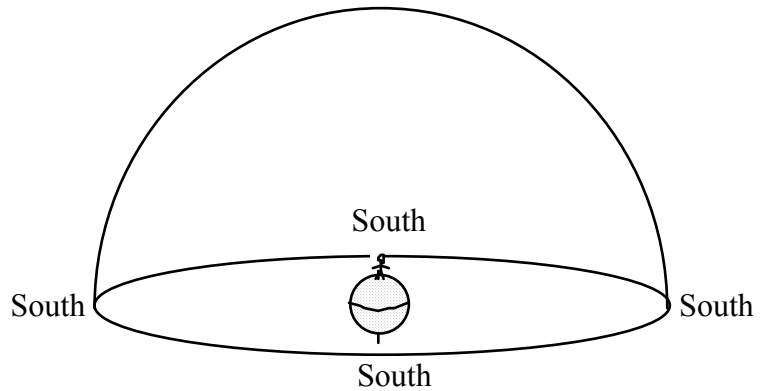
At the Equator (0° Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise	East		
Altitude (angle to horizon) of sun at noon	90°		
Location of sunset	West		
# of hours of daylight	12		

Draw the North Star, the Celestial Equator and all three paths of the sun.



At the North Pole (90° N. Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise			
Altitude (angle to horizon) of sun at noon			
Location of sunset			
# of hours of daylight			

Draw the North Star, the Celestial Equator, and all three paths of the sun.



Practice Lecture Exam #2

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Some Comments on the Real Exam

- This exam covers all material related to astronomy. Specifically, this exam covers:
 - All of Part C of your course packet
 - Planetarium Lab #1 (p. A-65 through A-68)
 - The moon project
- Be sure to bring the following items to the exam: Cardboard solar motion model
Star and Planet locator

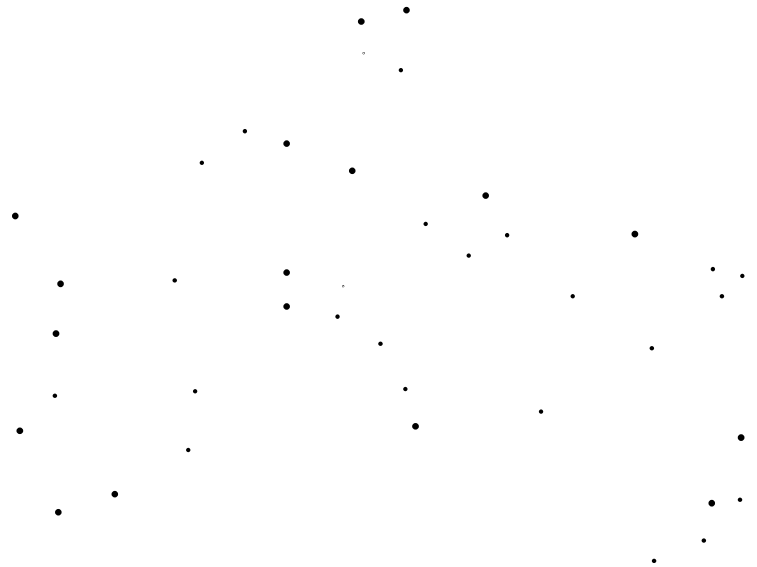
Part 1: The Circumpolar Constellations

Materials

Model Celestial Sphere

Questions

1. Circle and name the five circumpolar constellations illustrated below. Identify and label the North Star.



2. Describe and illustrate how you can use the North Star to determine your latitude.

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3. Explain why the North Star “stands still.”

Part 2: Celestial Hemispheres

Useful Information

- On the equinoxes (March 21 and September 21), the angle of the noonday sun is $90^\circ - (\text{your latitude})$.
- On the summer solstice, the angle of the noonday sun is $90^\circ - (\text{your latitude}) + 23.5^\circ$.
- On the winter solstice, the angle of the noonday sun is $90^\circ - (\text{your latitude}) - 23.5^\circ$.
- In any 24-hour period, the sun always appears to travel parallel to the Celestial Equator.

Materials

Cardboard solar motion models

Clear plastic hemisphere

Pens designed for overhead projectors

Introduction: Imagine yourself in the middle of a very large flat treeless plain, looking up at the sky. The sky above you looks like a giant inverted bowl. You are inside the bowl, in the exact center. The sun, moon, planets and stars seem to move on the surface of this huge bowl.

We will now scale down this image. Imagine that you are the size of a pinhead. The lab table is the large flat plain and the small clear plastic hemisphere is the bowl that represents the sky.

Activity/Questions

On the clear plastic hemisphere (representing the sky above you), draw the path of the sun across the sky in Chico (latitude 40° N) for each of the following dates:

- a. Vernal Equinox (around March 22)
 - b. Autumnal Equinox (around September 22).
 - c. Summer Solstice (around June 22)
 - d. Winter Solstice (around December 22)
- Be sure to label “North” on the sphere.
 - Be sure to draw the paths at the correct compass directions and at the correct angles from the horizon (as close as you can get them).
 - Describe how you figured out the paths, showing all the steps of any mathematical calculations you did.

Part 3: The Path of the Moon Across the Sky

Background Information

Most people know their astrological sun sign, but many people don't know that they also have a "moon sign," (and a "Venus sign," a "Mars sign," etc.). Each of your "signs" is designated by the position of that celestial object in the sky, relative to the constellations of the Zodiac, at the time you were born. We will not ask you to comment on the significance (or insignificance) of your various signs with regard to your personality and future--those issues fall within the spiritual realm, not within the realm of science. But, we will ask you to explain why and over what period of time the moon travels through the various constellations of the Zodiac.

The plane of Earth's orbit around the sun is tilted at a 23.5° angle to the Earth's equator. By contrast, the plane of the moon's orbit around the Earth is tilted at a 5° angle to the plane of the Earth's orbit around the sun. As a result, the apparent path of the moon across the sky is a little different from the apparent path of the sun across the sky. But, for the purposes of this activity, these differences don't matter and we will use the model "Sun" on the Model Celestial Sphere to represent the moon.

Materials: Model Celestial Sphere

Activity: Turn the white knob on the outside of the Celestial Sphere to model the revolution of the moon around Earth. Note the path of the moon relative to the constellations of the Zodiac.

Questions:






1. How long does it take the moon to complete one cycle through the constellations of the Zodiac? Explain.
2. Explain why the moon travels through the constellations of the Zodiac.
3. The chronological order of the "Sun signs" is Capricorn–Aquarius–Pisces–Aries–Taurus–Gemini–Cancer–Leo–Virgo–Libra–Scorpio–Sagittarius. Do the moon signs go in the same order or do they go backwards? Explain.
4. How many days (approximately) does the moon take to travel through each sign of the zodiac?

Part 4: The Moon

Materials: White polystyrene ball on a pencil (to represent the moon)
 Glowing light bulb (to represent the sun)

Activity: Use the ball on the stick and the light bulb to model the moon in its various phases.

1. Complete the table below, inserting the names of the moon phases, drawings of the moon and/or drawings of the positions of the moon, sun and Earth as appropriate. In your drawings of the moon, please leave the lit portion of the moon white and shade in the dark portion of the moon.

Moon Phase	Drawing of what the moon looks like from Earth (northern hemisphere)	Drawing of Positions of moon, sun and Earth (<u>looking down on Earth's North Pole</u>)
Waxing Gibbous		Sun)
1 st Quarter		Sun)
		Sun)
		Sun)
		Sun) Moon ○ Earth ⊙

2. Questions about the photograph on the front cover of the course packet.

Photographers: Crew of the Apollo 8 NASA mission to the moon

Date of photograph: December 22, 1968

Title of photograph: View of rising Earth about five degrees above the Lunar horizon

Explanation: The rising Earth is about five degrees above the lunar horizon in this telephoto view taken from the Apollo 8 spacecraft near 110° east longitude. The horizon, about 570 kilometers (250 statute miles) from the spacecraft, is near the eastern limb of the Moon as viewed from the Earth. On the earth, the sunset terminator crosses Africa. The South Pole is in the white area near the left end of the terminator. North and South America are under the clouds. The lunar surface probably has less pronounced color than indicated by this print.

Questions

- Why did the Earth look like a lop-sided football instead of a full circle?
- What were the relative positions of the sun, Earth and moon on December 22, 1968?
- On that same day (December 22, 1968), what did the moon look like from Earth (i.e. what was the phase of the moon?)
- Why is the South Pole “up?”
- From any one place on the moon, does Earth ever really “rise” or “set?”

Part 5: Multiple Choice

- Why is it hotter at the equator than at the poles?
 - Because the equator is closer to the sun.
 - Because the sun's rays travel through more atmosphere at the equator.
 - Because the sun's energy is more spread out at the equator.
 - Because the sun's rays hit the earth's surface at a higher angle at the equator.
 - Because the sun is always directly overhead at the equator.
- If the Earth's axis only had a 5° tilt, how would the seasons in Chico be different from how they are now?
 - The seasons would be shorter.
 - The transitions between seasons would be more abrupt.
 - The contrast in temperature between summer and winter wouldn't be as great.
 - Summer days would be longer than they are now and winter days would be shorter than they are now.
 - All of the above.
- In Chico, the highest the sun ever gets at noon is _____ $^\circ$ above the horizon and the lowest the sun ever gets at noon is _____ $^\circ$ above the horizon.
 - 90° ; 40°
 - 73.5° ; 26.5°
 - 63.5° ; 40°
 - 47° , 23.5°
 - 40° ; 16.5°

4. You have been kidnapped and taken, blindfolded, to a remote site. You manage to peek outside one night and see the little dipper setting below the horizon. What is the approximate latitude of your location?
- 0° (Equator)
 - 40° North
 - 40° South
 - 90° North (North Pole)
 - 90° South (South Pole)
5. We can see Orion in November but not in May because in November _____ whereas in May _____.
- Orion is directly above North America; Orion is directly above Europe.
 - Earth tilts toward Orion; Earth tilts away from Orion.
 - Polaris is high in the sky; Polaris is below the horizon.
 - The sun is in Orion; the sun is opposite Orion.
 - Earth is between the sun and Orion; the sun is between Earth and Orion.
6. "Each star seems to rise a little later each day." True or false? Why?
- True, because the stars revolve very slowly around Earth in the same direction that Earth rotates on its axis.
 - True, because the sun moves through the constellations of the Zodiac from west to east.
 - False. Actually, each star seems to rise a little earlier each day because the earth rotates a little farther than 360° every 24 hours.
 - False. Actually, each star rises at the same time every day because the position of each star is fixed on the Celestial Sphere.
7. The diagram below shows one possible configuration of the Earth and Moon. The white sides of the circles represent the sides that are lit up by the sun, which is too far away to show. The black sides are in shadow.



Note: The relative sizes of the Earth and Moon are correctly shown on this diagram but the distance between them is not to scale (to make the diagram to scale, the Earth and Moon would have to be shown 10x as far apart).

What would the moon look like from Earth?



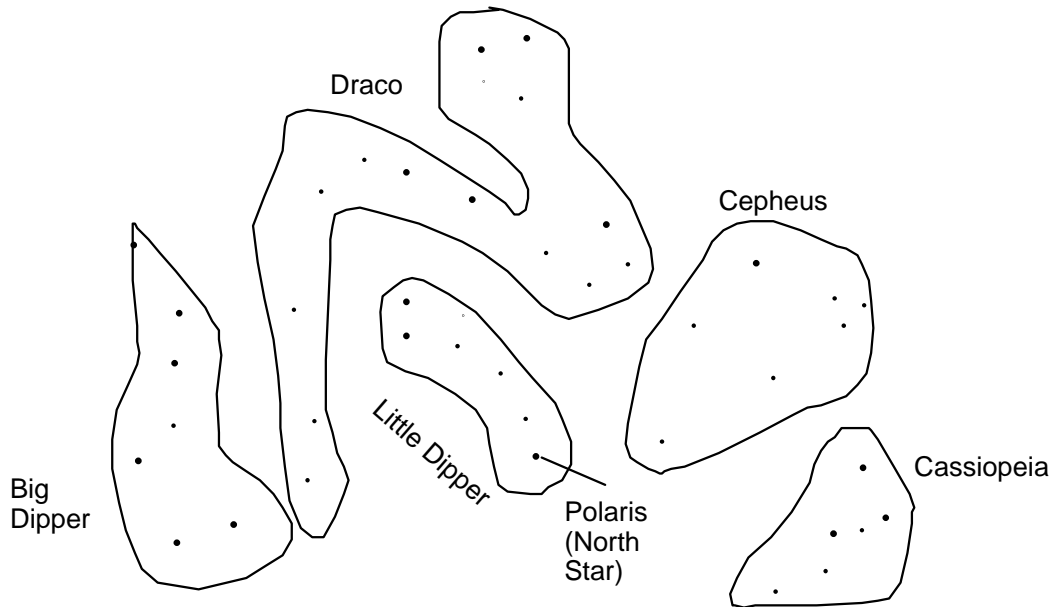
Practice Lecture Exam #2 - Answer Key

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Part 1: The Circumpolar Constellations

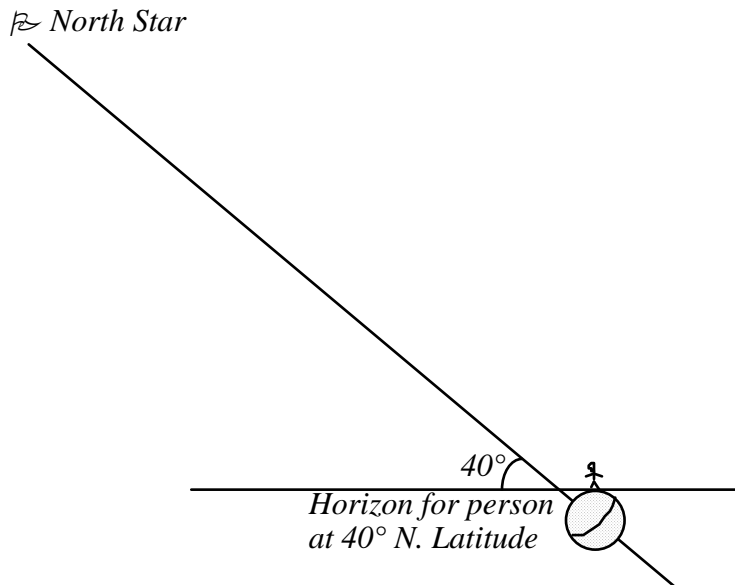
Questions

1. Circle and name the five circumpolar constellations illustrated below. Identify and label the North Star.



2. Describe and illustrate how you can use the North Star to determine your latitude.

At every place in the northern hemisphere, the altitude of the north star above the horizon is exactly equal to the latitude of that place.



3. Explain why the North Star “stands still.”

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As shown in the previous diagram, Earth's axis points directly at the North Star. Therefore, looking at the North Star is like looking at a spot on the ceiling directly above you as you spin around on a lab stool or other spinnable chair. That spot on the ceiling is aligned with your axis of rotation, so it does not appear to move. However, because you are spinning, it looks to you like everything but that spot is spinning in a circle around that spot.

Part 2: Celestial Hemispheres

Useful Information

- On the equinoxes (March 21 and September 21), the angle of the noonday sun is $90^\circ -$ (your latitude).
- On the summer solstice, the angle of the noonday sun is $90^\circ -$ (your latitude) $+ 23.5^\circ$.
- On the winter solstice, the angle of the noonday sun is $90^\circ -$ (your latitude) $- 23.5^\circ$.
- In any 24-hour period, the sun always appears to travel parallel to the Celestial Equator.

Activity/Questions

On the clear plastic hemisphere (representing the sky above you), draw the path of the sun across the sky in Chico (latitude 40° N) for each of the following dates:

- Vernal Equinox (around March 22)
 - Autumnal Equinox (around September 22)
 - Summer Solstice (around June 22)
 - Winter Solstice (around December 22)
- Be sure to label "North" on the sphere.
 - Be sure to draw the paths at the correct compass directions and at the correct angles from the horizon (as close as you can get them).
 - Describe how you figured out the paths, showing all the steps of any mathematical calculations you did.

Answer: See the plastic hemisphere for the paths.

Angle of the noonday sun above the southern horizon (the sun is always exactly in the south at noon):

Vernal Equinox	50°
Summer Solstice	73.5°
Autumnal Equinox	50°
Winter Solstice	26.5°

The easiest way to draw these paths correctly is to use the cardboard solar motion models.

Precise calculations (using the information given in the question):

$$\text{Equinoxes: } 90^\circ - (\text{our latitude}) = 90^\circ - 40^\circ = 50^\circ$$

$$\text{Summer Solstice: } 90^\circ - 40^\circ + 23.5^\circ = 73.5^\circ$$

$$\text{Winter Solstice: } 90^\circ - 40^\circ - 23.5^\circ = 26.5^\circ$$

Part 3: The Path of the Moon Across the Sky

Questions:

1. How long does it take the moon to complete one cycle through the constellations of the Zodiac? Explain.

It takes 27 days for the moon to complete one cycle through the constellations of the Zodiac. This is because it takes that long for the moon to make a full 360° circle around Earth. Note that it takes LESS time for the moon to complete one cycle through the constellations of the Zodiac than it takes the moon to complete one cycle of phases.

2. Explain why the moon travels through the constellations of the Zodiac.

The moon travels through the constellations of the Zodiac because it orbits around us in about the same plane that we orbit the sun.

3. The chronological order of the “Sun signs” is Capricorn–Aquarius–Pisces–Aries–Taurus–Gemini–Cancer–Leo–Virgo–Libra–Scorpio–Sagittarius. Do the moon signs go in the same order or do they go backwards? Explain.

The moon signs go in the same order as the sun signs. This is because the moon orbits the earth in the same direction that we orbit the sun (counterclockwise, looking down on the North Pole).

4. How many days (approximately) does the moon take to travel through each sign of the zodiac?


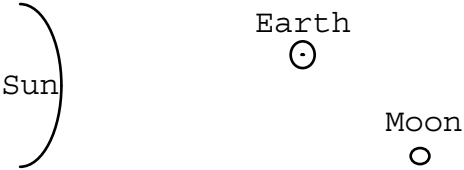



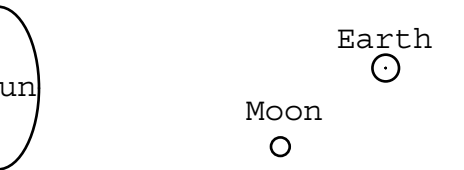




It takes the moon 27 days to travel through all 12 signs. $27 \div 12 = 2 \frac{1}{4}$. So it takes $2 \frac{1}{4}$ days for the moon to travel through each sign.

Part 4: The Moon

Materials: White polystyrene ball on a pencil (to represent the moon)
Glowing light bulb (to represent the sun)

Activity: Use the ball on the stick and the light bulb to model the moon in its various phases.

1. Complete the table on the next page, inserting the names of the moon phases, drawings of the moon and/or drawings of the positions of the moon, sun and Earth as appropriate. In your drawings of the moon, please leave the lit portion of the moon white and shade in the dark portion of the moon.

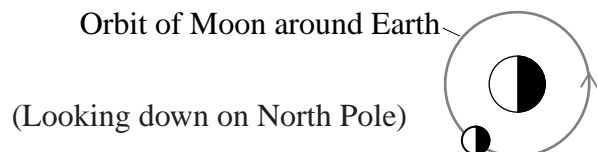
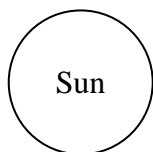
Moon Phase	Drawing of what the moon looks like from Earth (northern hemisphere)	Drawing of Positions of moon, sun and Earth (<u>looking down on Earth's North Pole</u>)
Waxing Gibbous		
1 st Quarter		
Waxing Crescent		
Waning Gibbous		
Waning Crescent		

2. Questions about the photograph on the front cover of the course packet.

a. Why did the Earth look like a lop-sided football instead of a full circle?

The Earth was “gibbous” because the moon and Earth were not perfectly in line with the sun.

b. What were the relative positions of the sun, Earth and moon on December 22, 1968?



- c. On that same day (December 22, 1968), what did the moon look like from Earth (i.e. what was the phase of the moon?)

The moon was in waxing crescent phase.

- d. Why is the South Pole “up?”

The photograph was taken from what looks to us in the northern hemisphere like the “bottom” of the moon. From there, when you look at Earth, the northern hemisphere of Earth is on the “bottom.”

- e. From any one place on the moon, does Earth ever really “rise” or “set?”

No, it doesn't! The same side of the moon is always facing Earth

Part 5: Multiple Choice

1. d
2. c
3. b
4. a
5. e
6. c
7. b

