

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?

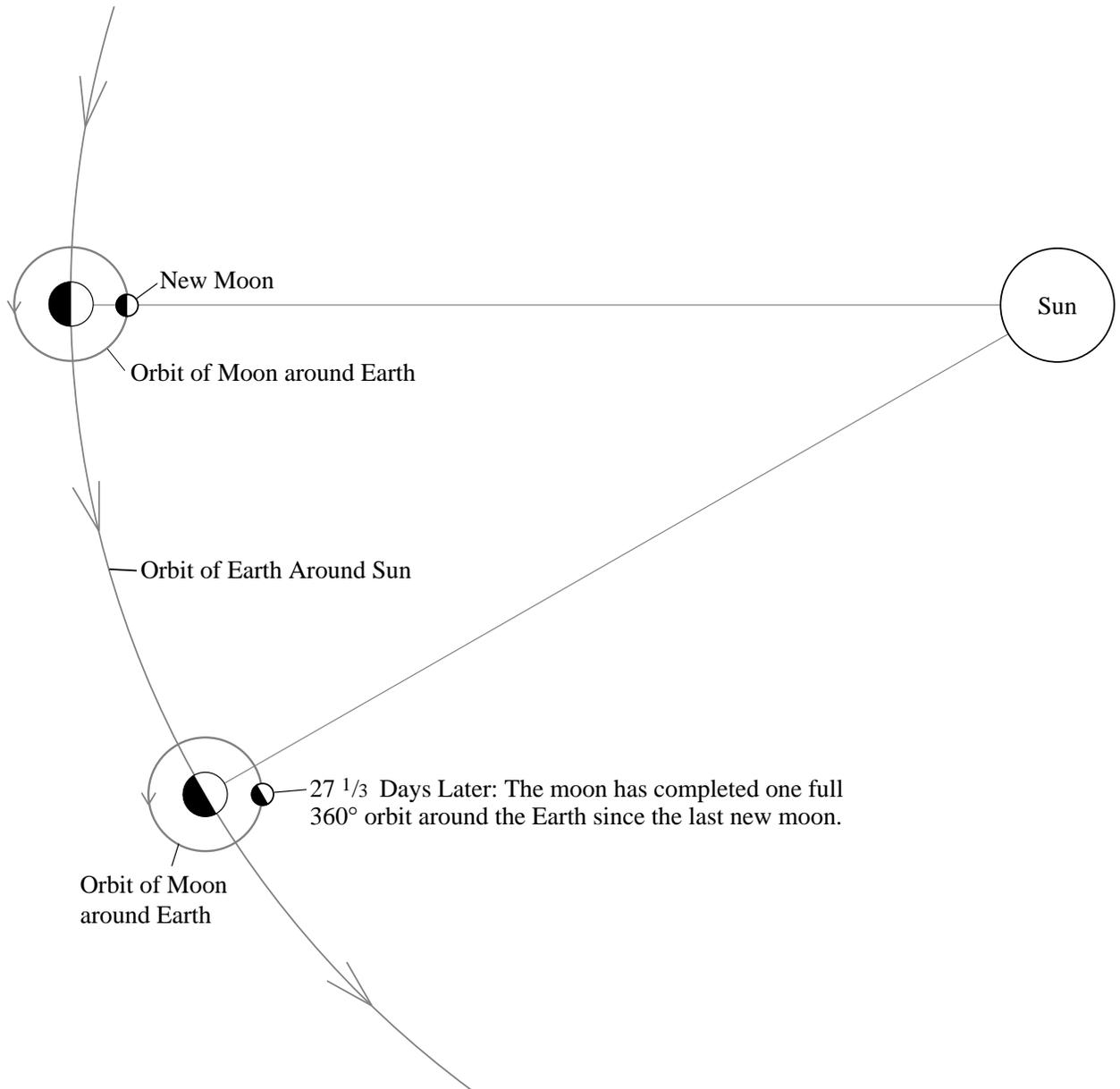
C. Lunar Motions (p. 617–618)

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?

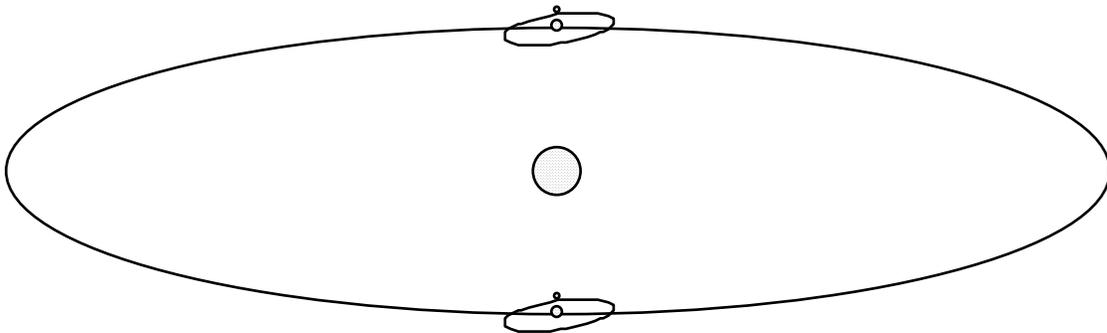
3. Why is a synodic month longer than a sidereal month? In answering this question, add to the diagram below.



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 #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 #9: 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

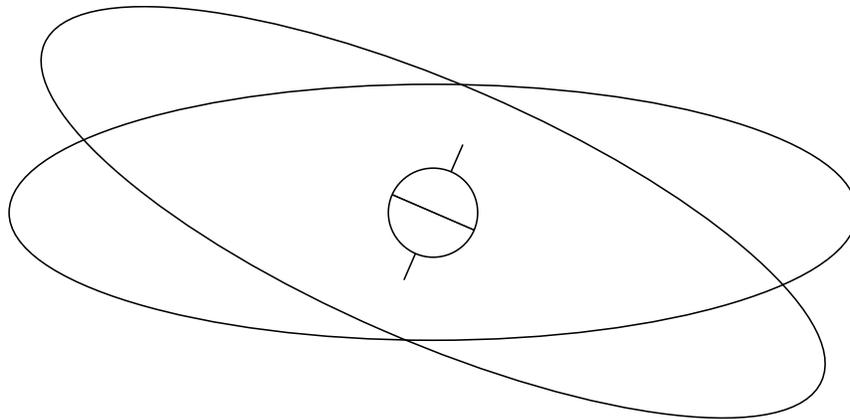
1. Apparent path of the sun
 - a. Over the course of a year, why does the sun appear to move relative to the stars? In addition to reading the text, carefully study Figure 21.C on p. 612.

 - 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) _____

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.

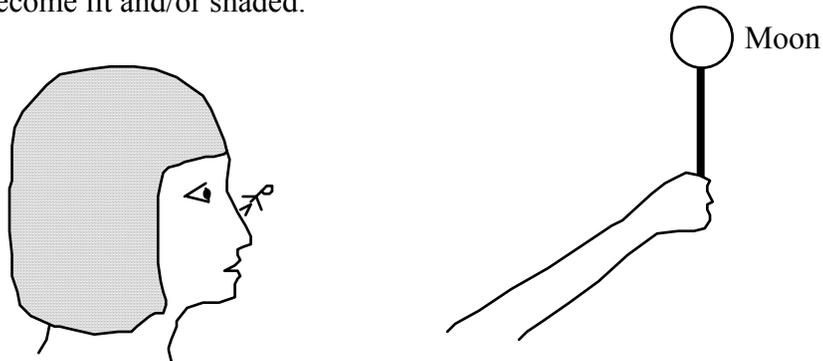
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Lab Activity #2: Modeling the Phases of the Moon³

Materials: White polystyrene ball, 3 inches in diameter (to represent the moon)⁴
 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):

³This 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).

⁴A 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. 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.⁵ 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 waxing⁶ 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? _____

⁵ 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.

⁶ 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, darken⁷ 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).⁸
5. “Below” each sketch of the moon, write the approximate day in the moon's 29-day cycle.

⁷Darken the part of the moon that is not visible; leave the “lit” portion of the moon white.

⁸ 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: What Causes Solar and Lunar Eclipses?⁹

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?¹⁰ _____

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.

⁹This 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).

¹⁰ 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 #7: 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 apart¹¹ in a line with the projector so as to model a lunar eclipse true to scale.¹²
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.

Questions:

1. Why don't we have a lunar eclipse every month? Draw a diagram to illustrate your answer.
Hint: the plane of the moon's orbit around the earth is 5° off of the plane of the earth's orbit around the sun.
2. Will a lunar eclipse be visible from every place on Earth that is facing the moon? Explain the reasoning behind your answer and draw a diagram to illustrate your answer.
3. A lunar eclipse only lasts a few hours. Why?

¹¹ Note: the tiles in the room are exactly one foot square.

¹² 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: 12 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 (there isn't one given for Alpha Centauri).

List the model objects that you used for each item in the solar system:

Real Object	Model Object
Sun	Large 28 inch yellow ball
Mercury	
Venus	
Earth	
Earth's moon	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Pluto	

- b. Go outside to the Children's Playground and make a scale model of the solar system as far out as Mars. Put the sun on the north (creek) side of the park. As a class, walk from the "sun" to the location of each planet, leaving a lab stand on the ground to mark the location of each planet so that you can see it from the next planet out. Note the apparent size of the "sun" from Earth--it should look about as large as the real sun looks in the sky.

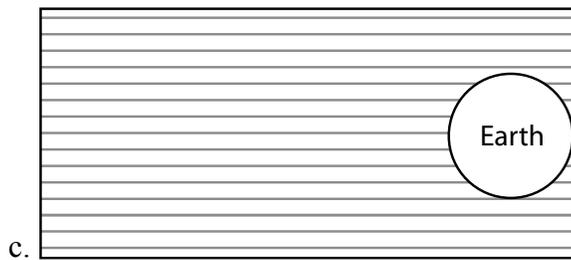
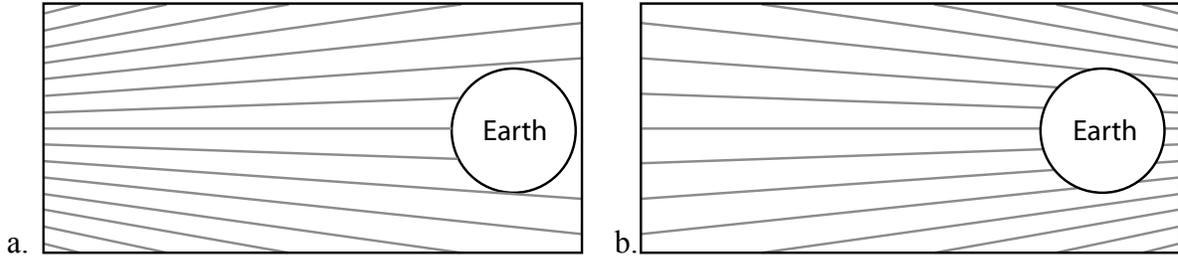
For those who might wish to make a model of the entire solar system at this scale, here are the locations of the planets beyond Mars on this scale model.

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.
Pluto	Where Park turns east and heads toward the freeway

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. Which diagram below 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.

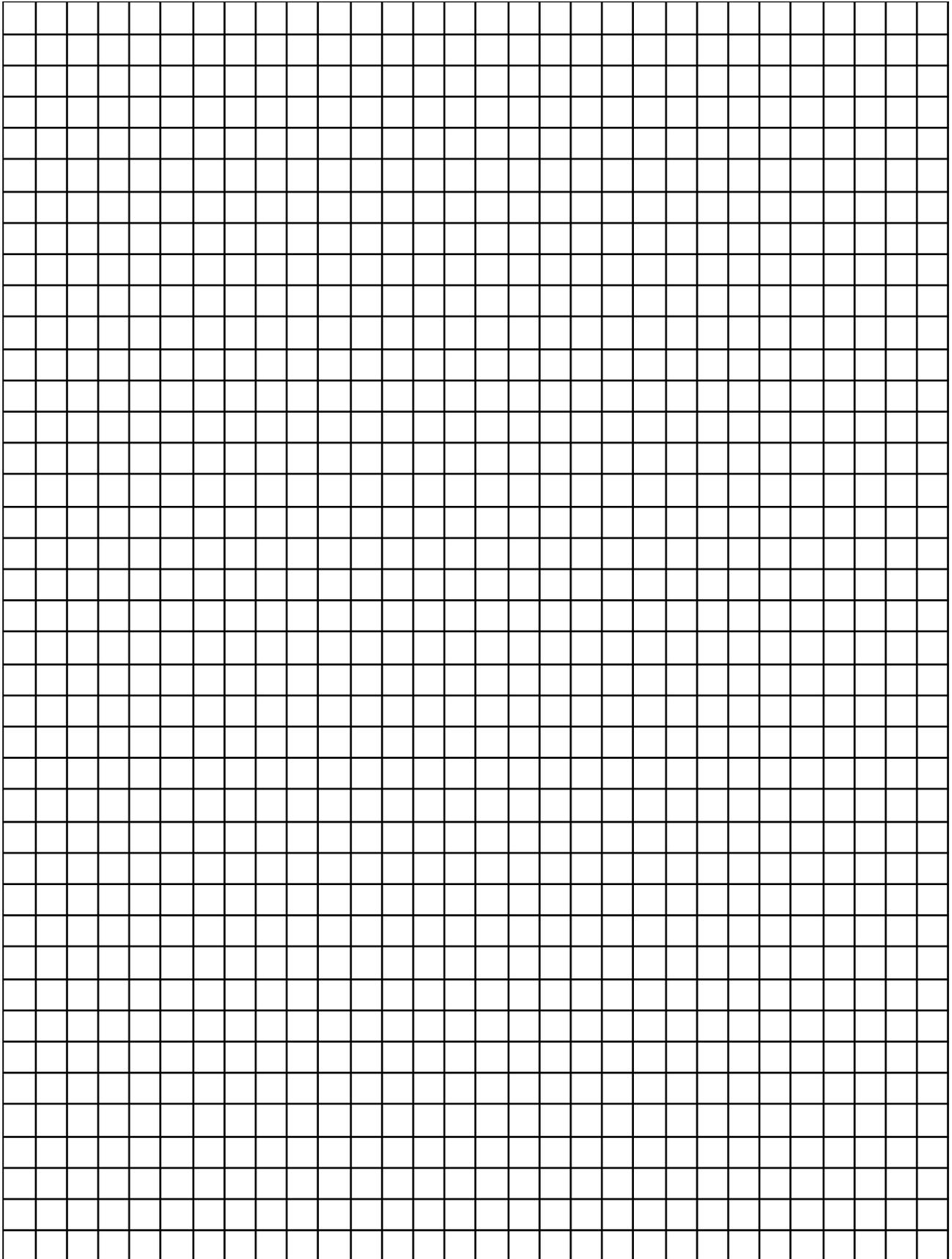
6. Imagine tiny people standing at various latitudes on your globe. Would all of these people see a **noonday** sun directly overhead, or would there be some variation? Explain. Draw a diagram to illustrate your answer.

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, holding the flashlight 2–3 inches above the paper. On the paper, outline the middle (bright) spot.
 2. From the same height, shine the flashlight at an angle to your grid paper. Again, outline the middle (bright) spot.
7. 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°).
 8. Clearly and fully explain why the angle at which light strikes a surface affects the intensity of the light energy felt by that surface.

9. 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. Draw a diagram to illustrate your answer.

10. 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 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 on page C-27 of this lab manual notes 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 circular¹³. The table below provides Earth's average distance from the sun during selected months of the year.¹⁴

Month	Average Earth-Sun Distance ¹⁵
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.

¹³**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%.

¹⁴For 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).

¹⁵**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.

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.

Question: What is special about the Tropics of Cancer and Capricorn at the solstices that can account for the above observations? Use your model for the seasons to explain how.

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? Use your model for the seasons to explain how.

Planetarium Lab #2: Variations in the Sky With Latitude & Season

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Introduction

Up until this point, we have spent our time in the planetarium focusing on the *apparent daily* motion of the stars as seen from Chico. This motion is due to Earth's rotation and is the same day after day, year after year¹⁶. We will now focus on two more complicated concepts:

- 1) Apparent daily motion of the stars as seen from the equator and from the North Pole.
- 2) The *apparent* long-term motion of the sun. The sun displays the same daily apparent motions as the stars do and, in the course of one day, it seems to maintain a fixed position with respect to the stars. However, if we carefully observe the sky for several days, weeks or months (similar to what you did as you conducted your moon study), we can detect a motion of the sun relative to the stars.¹⁷

In the planetarium, we can see what the night sky looks like at distant locations on earth without actually having to travel there. We can also make observations very efficiently by speeding up time. Best of all, we can take away the apparent motions that are caused by Earth's rotation. Imagine taking a photograph of the sky at exactly the same time every night for many nights in a row; if you put those photographs together and made a movie, it would be similar to what we can show in the planetarium. The planetarium also gives us the power to make the sun so dim that we can still see the stars during the daytime. In summary, using the power of the planetarium, we will not see any apparent daily motions due to the Earth's spin; we will only see the apparent annual motion of the sun due to the Earth's revolution around it.

Objectives

When you have completed this lab you should be able to

1. Use the altitude (angle above the horizon) of Polaris to determine your latitude.
2. Describe the apparent nightly motion of the stars as seen from the North Pole and from the Equator and explain why the stars seem to move the way they do at these locations.
3. 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.
4. Describe the difference between the Ecliptic and the Celestial Equator.
5. Discuss the astronomical basis for Astrology (movement of the sun, moon and planets through the signs of the Zodiac) and why scientists have no faith in Astrology.

¹⁶ We will ignore the motion of the stars relative to each other and the effects of the precession (gradual change in orientation) of Earth's axis, both of which happen so slowly that no human being can live long enough to notice.

¹⁷ It is this movement that caught the attention of early astrologers who, perhaps understandably, concluded that it had profound spiritual significance.

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Lab Activity #1: Modeling the Apparent Motion of the Sun Through the Constellations of the Zodiac

More Activity: (Do this activity as a whole class) One person represents the earth, another represents the sun and everyone else represents stars. Form a large circle with the “sun” in the center and the “earth” next to the sun. Space the various “stars” unevenly around the circle. Everyone stays in place except the “earth.” The “earth” will spin and orbit around the “sun” (be sure to spin and orbit in the proper directions).¹⁸

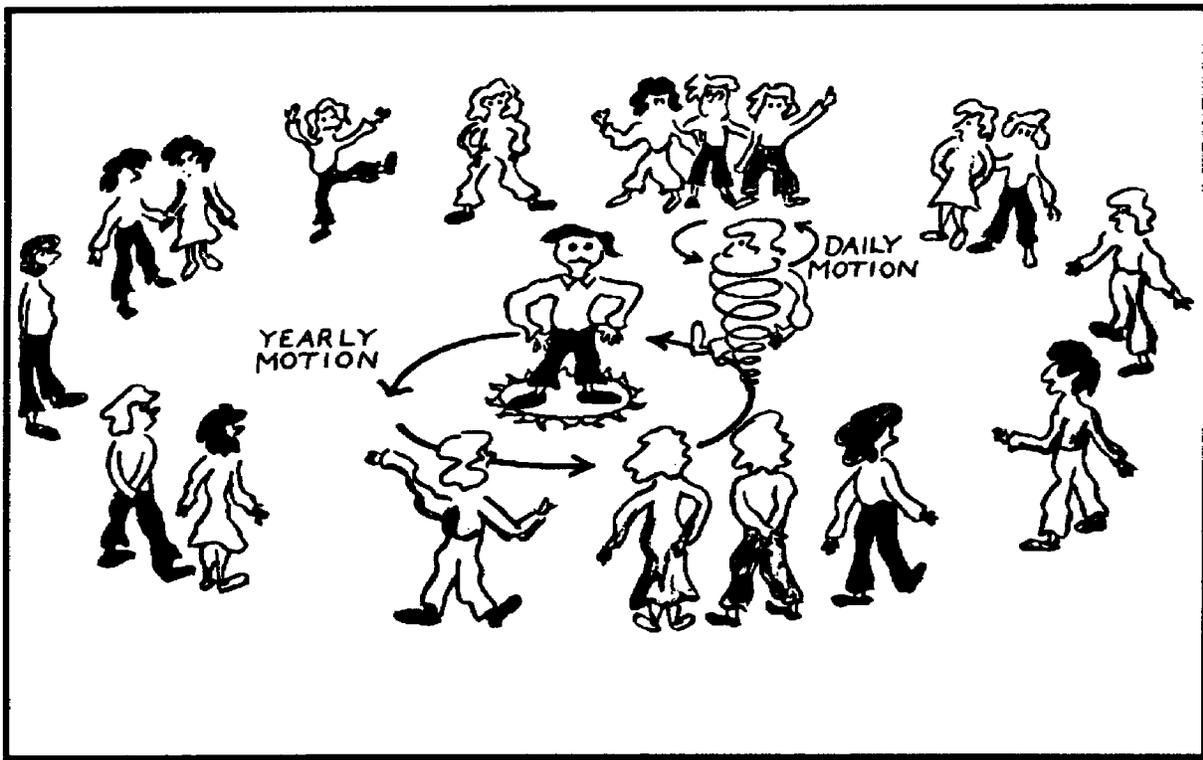


Illustration of the Activity

(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).

Lab Activity #2: Watching the Sun Move Through the Constellations of the Zodiac

Activity: Go into the planetarium. Your instructor will show what you would see if you continually kept your gaze on the same stars for a year and watched the apparent motion of the sun as Earth circled around it. The path apparently followed by the sun in this demonstration is called the *ecliptic*.

¹⁸The earth spins counterclockwise as seen from above the north pole. The earth orbits the sun counterclockwise as seen from above the sun's “north pole.”

Question: As the sun appears to move with respect to the stars, it passes “through” the twelve constellations of the Zodiac. What is causing this apparent motion of the sun across these constellations? Draw a diagram to illustrate your answer.

More Activity: The planetarium (and your “SC001 Constellation Chart”—handed out in class) shows the ecliptic as a smoothly curving line sweeping across the 12 constellations that correspond to the 12 signs of the Zodiac. Notice the dates inscribed along the ecliptic; each date marks the position of the sun (as seen from Earth) with respect to the background stars on that date.

Locate your birthday on the ecliptic. Then note the constellation that that location is “in” (or nearest to). 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.

Questions

1. Is the sun actually “in” your supposed sun sign constellation on your birthday? If not, which “sign” is it “in?”
2. For those who have done the reading for homework #9, explain why, for most people, the sun is not in the “proper” constellation on their birthday.

4. Right now (mid spring), Orion is visible as soon as the sun sets but it only stays up until around 9 p.m. By contrast, in October, Orion does not fully rise until 11 p.m. but it is visible the rest of the night. In June, you will never see Orion at all. Explain these changes in the time of the night that certain constellations are visible.

Lab Activity #4: How the Night Sky Changes with Latitude

Introduction

Using the Planetarium, we can project the sky as it looks from any location on Earth at any time on any day of the year. What we will do is use the planetarium to study the positions and apparent daily motions of the stars as seen from two key locations: the North Pole and the Equator (you already did this for 40° North latitude--where Chico is).

Activity: On the ceiling of the planetarium, observe the altitude of the North Star and the daily motions of the stars with respect to the horizon, as seen from the equator, the North Pole, and Chico.

Questions

1. Complete the table below

	Altitude of Polaris	Nightly Motion of the Stars With Respect to the Horizon
North Pole		
Equator		

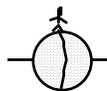
2. Describe a way to determine your latitude if you can measure the altitude of Polaris
3. Explain why Polaris is at different altitudes at different latitudes. To illustrate your answer, add to the diagrams below.



Person at the North Pole



Person in Chico (at 40° N. Latitude)



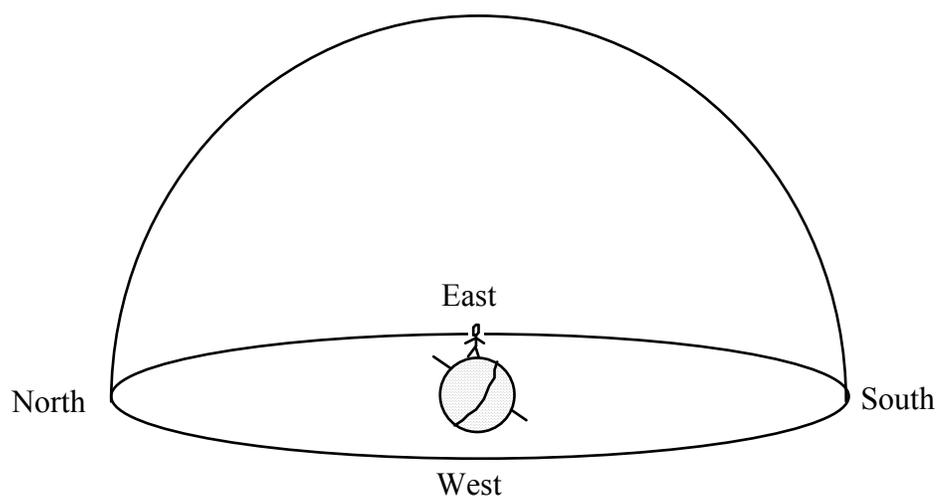
Person at the Equator

Lab Activity #5: The Apparent Path of the Noonday Sun

Activity: Your instructor will use the planetarium to show the path of the sun across the sky as you would see it (in Chico) if you looked up at the sky at the exact same time every day (our fixed time will be noon) and didn't look at any other time. As your instructor does this, notice that the background stars appear to move relative to the sun.

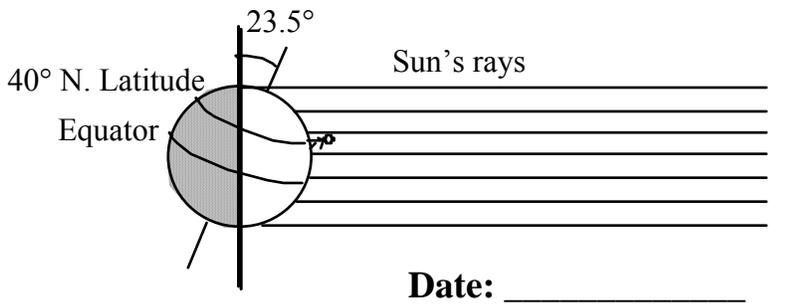
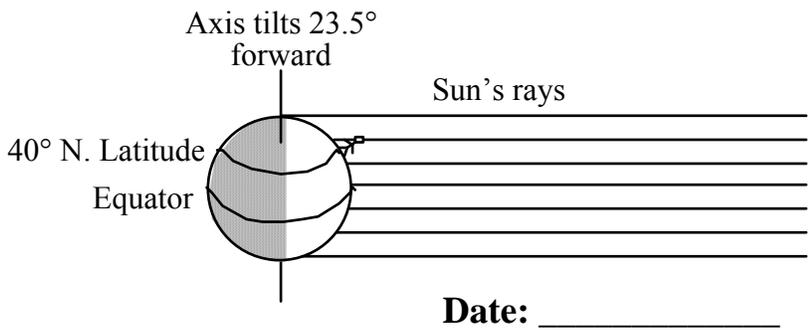
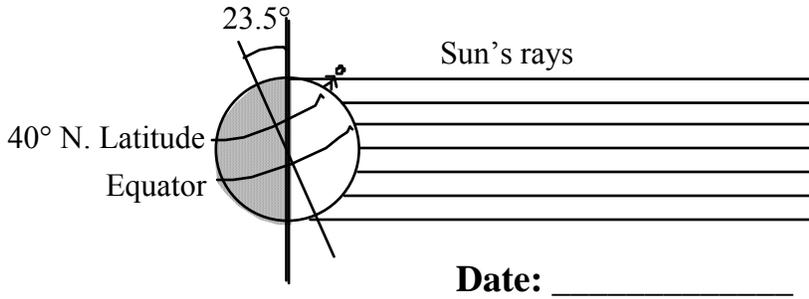
Questions

1. Draw the apparent path of the noonday sun (as seen from Chico) on the diagram below. Label the highest and lowest points with the appropriate dates.



2. What is the altitude of the noonday sun on the summer solstice (\pm June 21)? _____
3. What is the altitude of the noonday sun on the winter solstice (\pm December 21)? _____
4. What is the altitude of the noonday sun on the equinoxes (\pm March 21 and Sept. 21)? _____

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.



Lab Activity on Variations in the Apparent Daily Path of the Sun With Latitude and Season

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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. 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.
2. Determine the approximate altitude of the noonday sun in various places on various dates and explain why that angle changes with latitude and season.

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 = $90^\circ - (\text{your latitude}) - 23.5^\circ$

Lab Activity #1: The Apparent Daily Path of the Sun Across the Sky

Introduction: 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. This activity should deepen your understanding of the ramifications of Earth's tilt.

Materials: Celestial Globe
one *Solar Motion* model per person (You may keep them!)

Introduction to the Model Celestial Sphere: In this activity, you will use a celestial globe, which is a model of the celestial sphere just as a world globe is a model of the Earth. The stars are shown as white dots on a clear plastic sphere. The sun is a small yellow ball inside the clear plastic sphere and the earth is a larger ball in the center of the sphere.

As you are learning in Homework Assignment #9, the concept of a celestial sphere is useful for understanding the apparent motion of the stars in the sky, even though there really is no giant crystalline sphere--studded with stars--surrounding the Earth. As you do this activity,

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remember that not all aspects of the model celestial sphere are accurate (for example, the model earth is WAY too big and WAY too close to the sun; and the model sun goes around the model earth even though, as you well know, the earth actually revolves around the sun).

How to Use the Model Celestial Sphere

1. Twist the large white knob at the bottom of the model celestial sphere clockwise; this causes the Earth inside the Celestial Sphere to spin. Notice that the stars do not move, only the Earth does (the moon and the other planets would too--if they were incorporated into this model).
2. In order to model the sky as seen from Chico, tilt and rotate the model celestial sphere until Chico is at the "top" of the Earth. Hold the model celestial sphere above your head and look through the sphere at the stars depicted on the inside of the sphere. Try to identify some of the constellations.

Note: the configuration of the stars in each constellation looks correct--except the stars look way too big--only when you look at the inside surface of the sphere (you get a mirror image if you look at a constellation on the outside surface of the sphere). However, the printed labels look correct only when viewed on the outside surface of the sphere--very confusing, I know.¹⁹

Be sure to give EVERY member of your group a chance to do this activity.

3. In order to model the motion of the stars as seen from Chico, hold the celestial sphere model in the same position as you did for Step #2 (described above). Then hold the large white knob (the one that controls the model Earth) fixed--keeping Chico "on top" of the world as you slowly spin the outside of the Model Celestial Sphere counterclockwise--as seen from below. This may take two people.

Be sure to give EVERY member of your group a chance to do this activity.

Activity:

1. For each of the various locations and dates listed below, determine the apparent path of the sun across the sky using the Celestial Globe and the *Solar Motion* model.
2. Complete the appropriate boxes in the tables.

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 Altitude of Sun: Whenever the altitude of the sun at noon is something other than exactly 0° or exactly 90° , you may simply state whether the angle is $>45^\circ$ or $<45^\circ$.

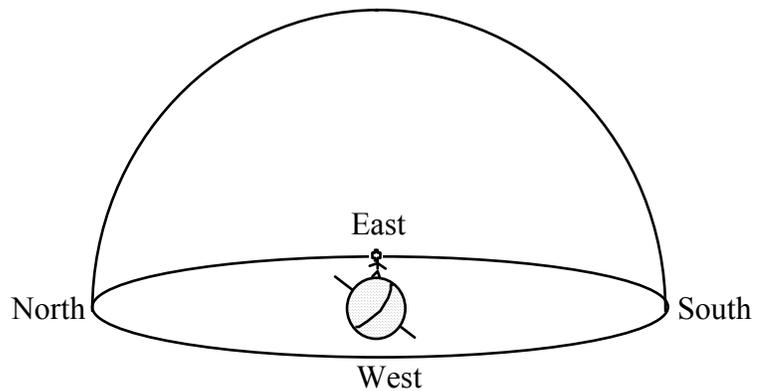
Note on Number of Hours of Daylight: Whenever the # of hours of daylight is not exactly 0, 12 or 24 yours you may simply state "Less than 12 hours" or "More than 12 hours."

¹⁹You could make a lot of money by designing and selling a model celestial sphere with constellation names that read correctly when you are looking at the inside surface of the sphere.

3. On the hemisphere diagrams provided, draw the path of the sun at the solstices and equinoxes for each location (Chico, Tropic of Cancer, Equator, and North Pole). In addition, draw the North Celestial Pole and the Celestial Equator on each hemisphere diagram. Note: The locations of the pole and equator will be different for each diagram.

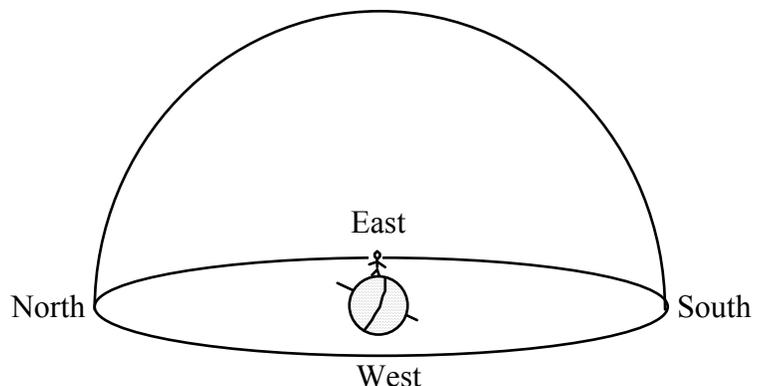
At Chico (40° N. Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise			
Altitude (angle to horizon) of sun at noon			
Location of sunset			
# of hours of daylight			

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



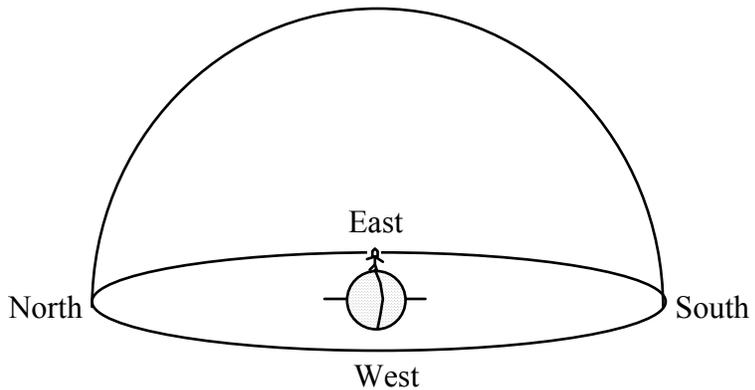
At the Tropic of Cancer (23.5° N. Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise			
Altitude (angle to horizon) of sun at noon			
Location of sunset			
# of hours of daylight			

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



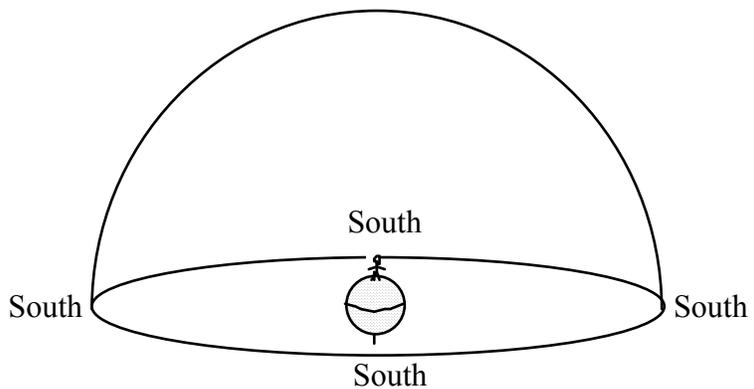
At the Equator (0° Latitude)	Equinoxes	Summer Solstice	Winter Solstice
Location of sunrise	East		
Altitude (angle to horizon) of sun at noon	90°		
Location of sunset	West		
# of hours of daylight	12		

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.



Lecture Notes: Earth's Place in the Universe

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A. Inventory of the Universe

1. Solar System

a. Definition:

b. # of Stars: _____

c. How is a star different from a planet?

d. Size and shape of our solar system:

e. What does our solar system look like from Earth?

f. What do other solar systems look like from Earth?

g. Our solar system is part of _____

h. How many solar systems are there?

i. How far apart are these solar systems?

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B. Motion in the solar system, galaxy, and universe

1. Motion of the earth within the solar system:

a. Orbit:

b. Wobble of Axis:

2. Motion of the solar system within the galaxy:

a. Spin:

b. Random motion:

3. Motion of the galaxy within the universe:

4. If there is so much rapid motion, why have the constellations remained the same for thousands of years?

Lecture Notes: The Solar System

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A. Review of Concepts Learned in the Lab “The Moon’s Phases and Eclipses”

1. Phases of the Moon

In the late 1960's and early 1970's, NASA sent a series of space missions to the moon. For the first time in Earth's history, people were able to view Earth as a whole on a single photograph--that is, they could see the part of Earth that faced them and was lit by the sun. You see, like the moon, Earth has phases.

On July 19, 1969, the Apollo 11 astronauts landed on the Sea of Tranquility (the Sea of Tranquility is not really a body of water; it is a huge basalt lava flow). Just before Neil Armstrong and Buzz Aldrin stepped out onto the moon for the first time, they took the picture of Earth that you see below (For those of you who saw the movie "Dish"--a great movie--you can now see why NASA had to use a satellite dish in Australia to broadcast the first moon walk).



On July 19, 1969, what did the moon look like from Earth? Was the moon waxing or waning? Explain.

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2. Solar Eclipses

- a. What is the umbra?
- b. What is the penumbra?
- c. Why do only a few people actually get to see each solar eclipse?

- d. Draw a series of three images of a solar eclipse.

- e. Which way does the moon move across the sun? _____
Why?

- f. What is the solar corona?

3. Lunar Eclipses

- a. Draw a series of three images of a lunar eclipse.

- b. Which way does Earth's shadow move across the moon?
Why?

4. Why don't we see eclipses every month?

B. Formation of the Solar System

1. Making the Elements

- a. Primordial matter of the universe:

- b. How does nature make heavier elements?

- c. How do you get those heavier elements out of the core of the star?

- d. An earlier star:

2. Making the Solar System

- a. Cloud of Dust

- b. The planets and sun are born
 - Stage 1

 - Stage 2

 - Stage 3

 - Stage 4

 - Stage 5

- c. How did our moon form?

F. Puzzle: Why are planets that are closer to the sun warmer than planets that are farther away from the sun? In other words, why is there a loss of intensity of electromagnetic radiation (heat, light, radio waves, microwaves, etc.) with distance?

1. Planets that are closer to the sun are warmer. Why?

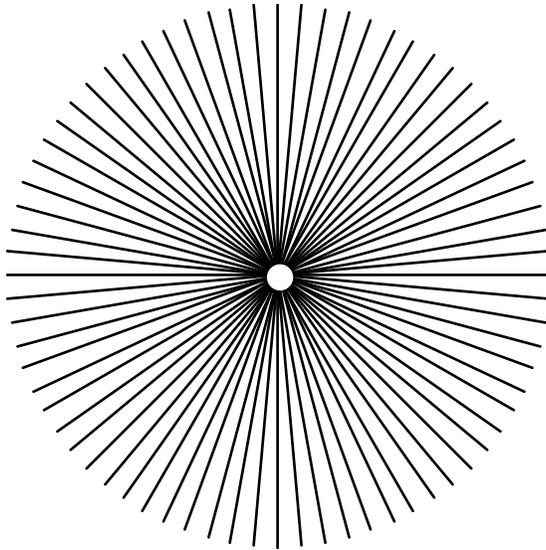
Simple answer: _____

2. More complex answer:

- a. It takes energy to move. Therefore a heat wave gradually loses energy as it travels.



- b. Heat waves spread out in all directions from a heat source. Therefore the concentration of energy decreases with distance.



- c. All of the above

Practice Exam #3

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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

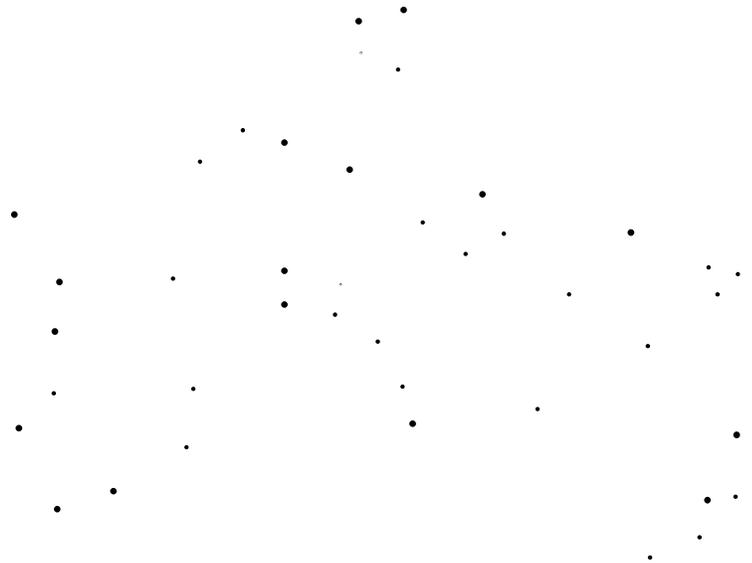
Part 1: The Circumpolar Constellations

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.

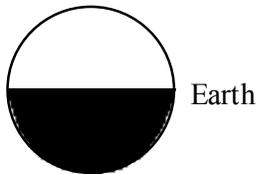
Questions

- 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?



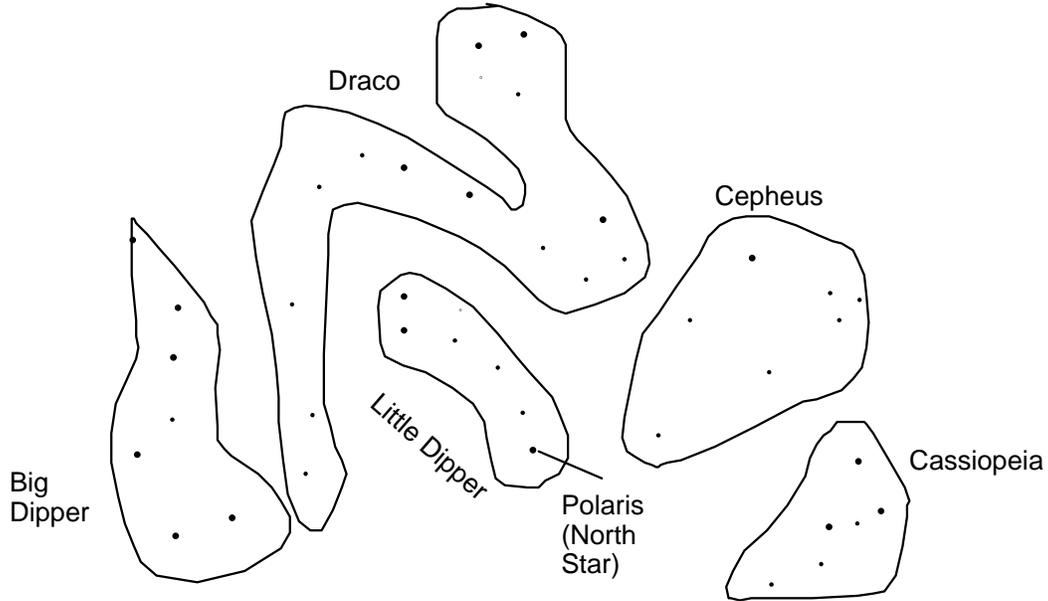
Practice Exam #3 - Answer Key

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Part 1: The Circumpolar Constellations

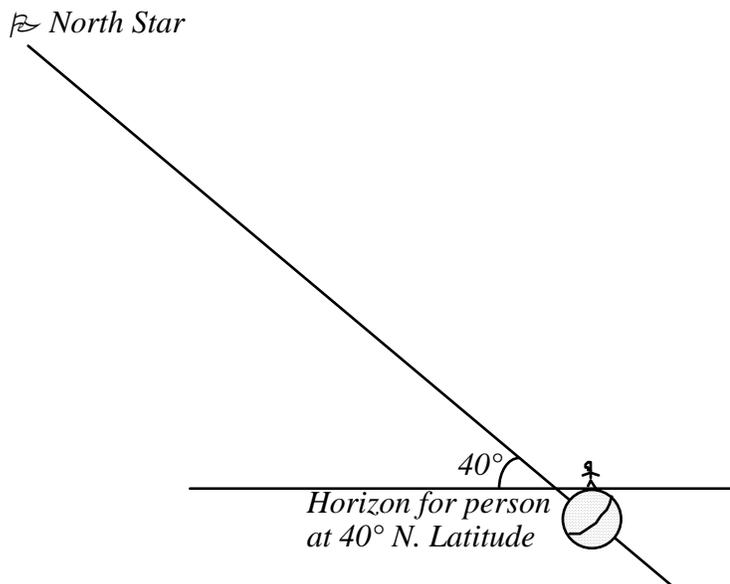
Questions

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.



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

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 HemispheresUseful 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):

<i>Vernal Equinox</i>	50°
<i>Summer Solstice</i>	73.5°
<i>Autumnal Equinox</i>	50°
<i>Winter Solstice</i>	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):

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

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

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?

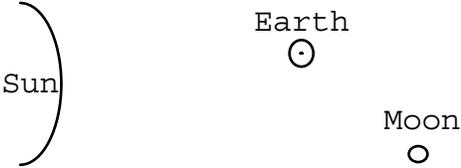
It takes the moon 27 days to travel through all 12 signs. $27 \div 12 = 2 \frac{1}{4}$. So it takes $2 \frac{1}{4}$ days for the moon to travel through each sign.

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.

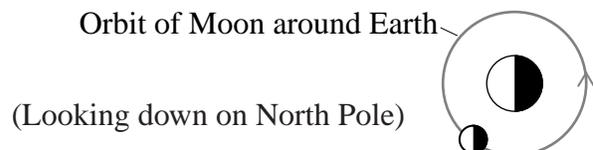
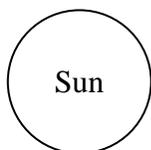
Moon Phase	Drawing of what the moon looks like from Earth (northern hemisphere)	Drawing of Positions of moon, sun and Earth (<u>looking down on Earth's North Pole</u>)
Waxing Gibbous		
1 st Quarter		
Waxing Crescent		
Waning Gibbous		
Waning Crescent		

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

The Moon Project: Topic 1 – Moon Rise and Set

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1. We all know that the sun rises in the east and sets in the west. But what does the moon do? Does it rise in the east and set in the west (like the sun does)? Or, since we know that the moon revolves around Earth from west to east, does the moon rise in the west and set in the east (the opposite of what the sun does)? Prove your answers using your observations. Explain WHY the moon rises where it does and sets where it does.

a. Look at the page of drawings you made each time you observed the moon twice in one day. For each pair of drawings, which direction did the moon move between your observations?

b. Where does the moon rise? _____ Where does it set? _____
Use specific observations, that you recorded on your data sheets, to prove your answer.

c. Materials: globe or person (to represent Earth)
toy figure, taped onto the globe at Chico (use Post-it tape ONLY)
polystyrene ball on a pencil or person (to represent the moon)
two sticky notes

Activity 1: Use the materials to model the motions that occur during one 24-hour day. Remember that it takes the moon about a month to revolve around Earth.

Question: What causes the moon to rise and set?

Activity 2: Use a person to represent the moon; turn the globe the way it really turns (which way is that?) until the “moon” can see California.

Question: Which direction (north, south, east, or west) would that person in California have to look to see the moon? Why?

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Activity 3

Label one sticky note “E” (for east) and one labeled “W” (for west). Use a person to represent Earth; put one sticky note on each cheek. Which sticky note goes on which cheek? Think about it! Have a different person hold up a ball-on-a-pencil to represent the moon.

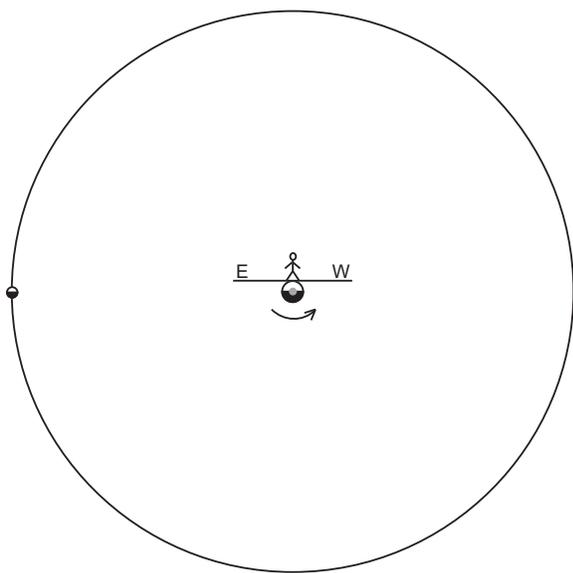
Earth: Sit on a stool. Start by facing away from the moon. Then spin the way Earth actually does (which way is that?) until you can just see the moon out of the corner of one eye. Is that the east eye or the west eye? Continue turning until you begin to lose sight of the moon, seeing it just out of the corner of one eye. Is that the east eye or the west eye?

Take turns being Earth and the moon.

Question: Why does the moon rise and set where it does? Draw a diagram to illustrate your answer.

2. The sun always rises in the morning and sets in the evening. The moon, on the other hand, rises and sets at any and all times of the day or night. Why? Is there any pattern to the changes in the times of moon rise and set? What is that pattern? Why does that pattern exist?
 - a. Look at your graph showing the time when the moon is out each day during a four-month period. This graph shows that, each day, the times of moonrise and moonset are slightly different from those of the day before. Describe how those times systematically change from one day to the next.

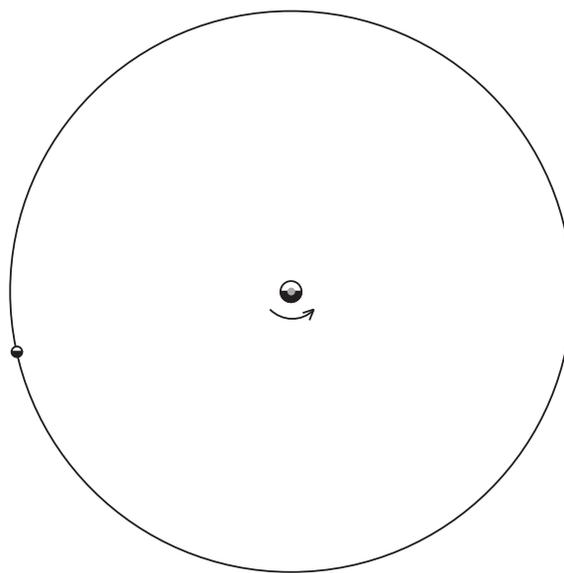
b. Answer the questions below these diagrams.



Moon rise / set

Approximate Time of Day _____

Phase of the moon _____



The next Day

Draw the person's position at moon rise

Approximate Time of Day _____

c. Use what you learned in question b to explain the cause of the pattern of moonrise and moonset change that you described in question a.

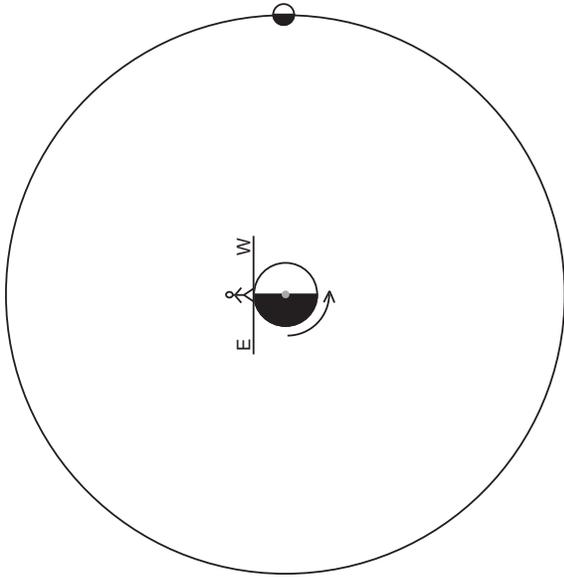
3. Is there any correlation between the times of moonrise/moonset and the phases of the moon? If so, clearly explain that correlation and explain and illustrate WHY this correlation exists.

- a. Look at your graph showing the time when the moon is out each day during a four-month period. Complete the table below.

Phase	Month	Moonrise Time	Moonset Time	General Description of Moonrise Time*	General Description of Moonset Time*
New Moon	September				
	October				
	November				
	December				
First Quarter	September				
	October				
	November				
	December				
Full Moon	September				
	October				
	November				
	December				
Third Quarter	September				
	October				
	November				
	December				

- b. Answer the questions on the next four pages. Then, in the space below, explain why those average times are what they are.

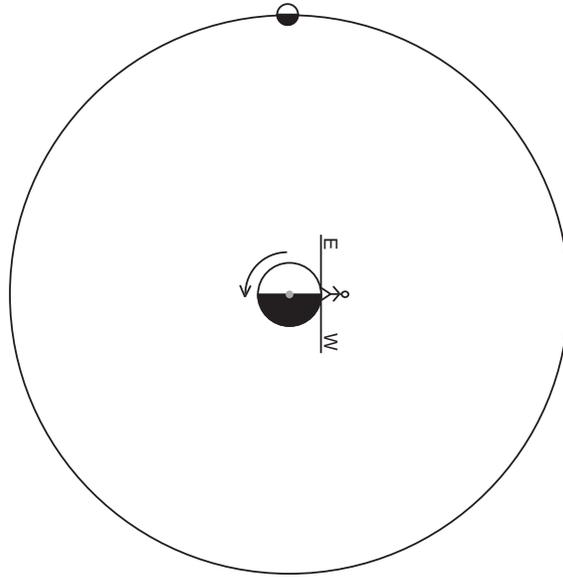
* Use phrases like “Around sunset,” “Around sunrise,” “Middle of the night,” or “Middle of the day.”



Moon rise / set

Approximate Time of Day _____

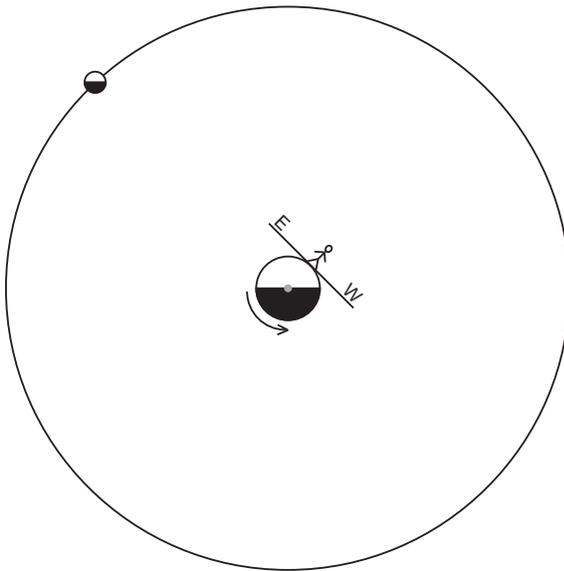
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

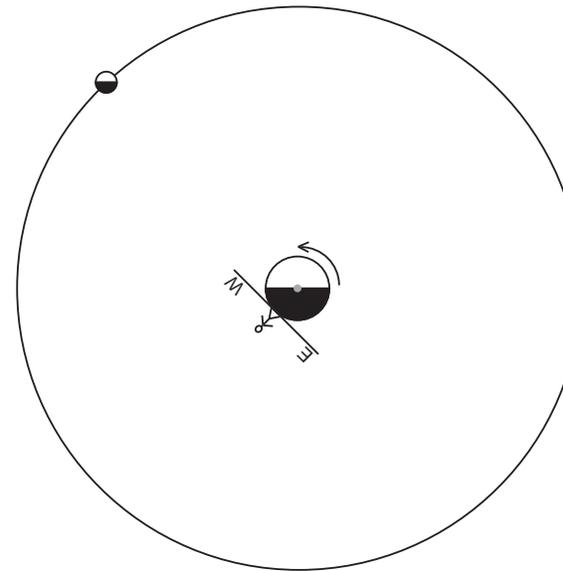
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

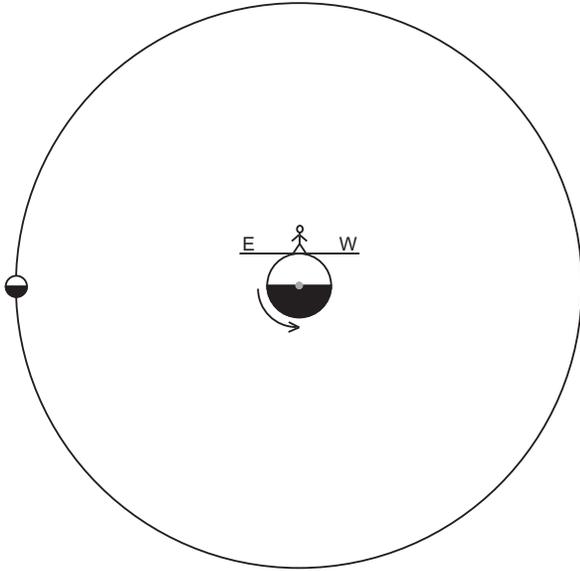
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

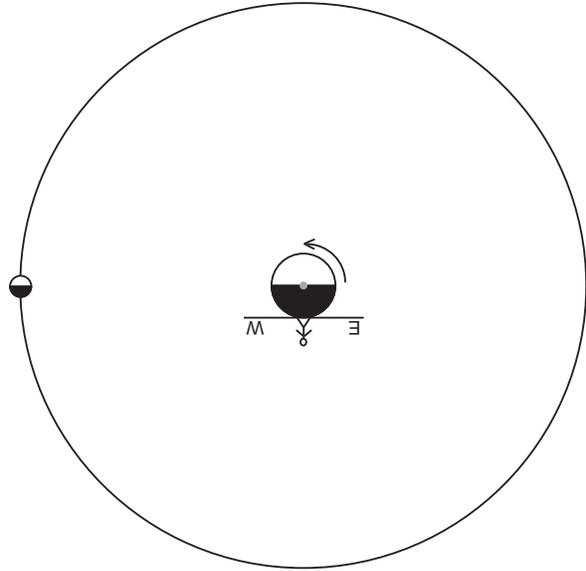
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

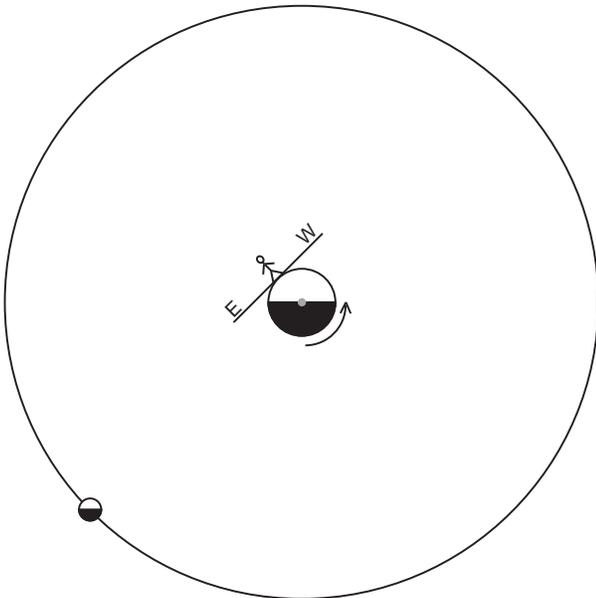
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

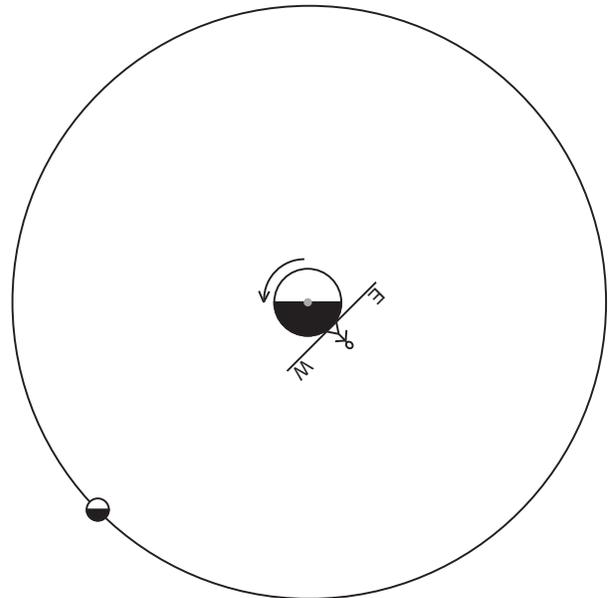
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

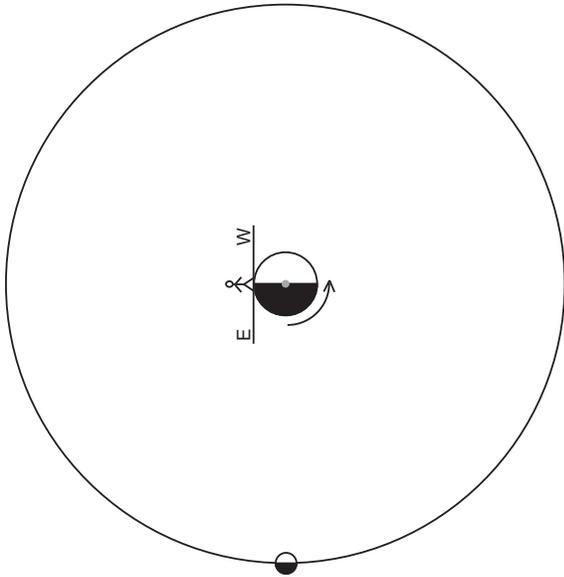
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

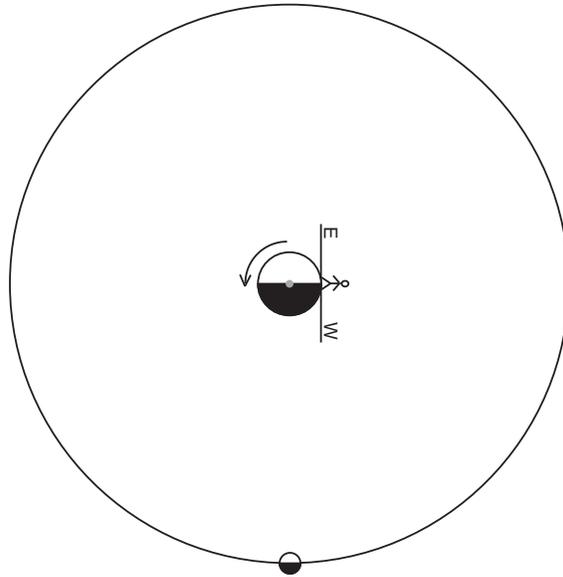
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

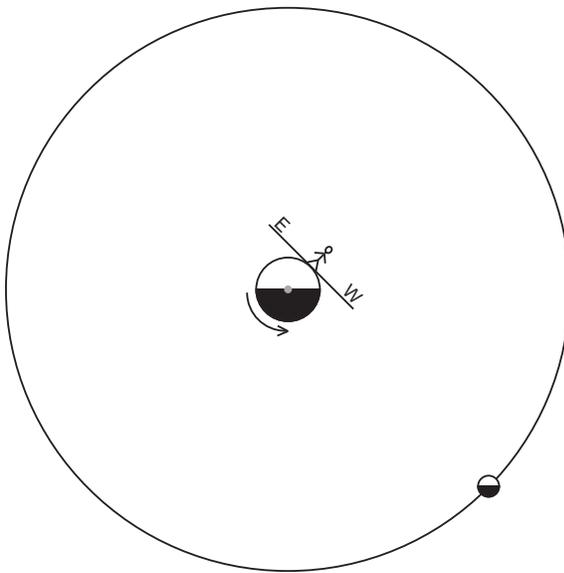
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

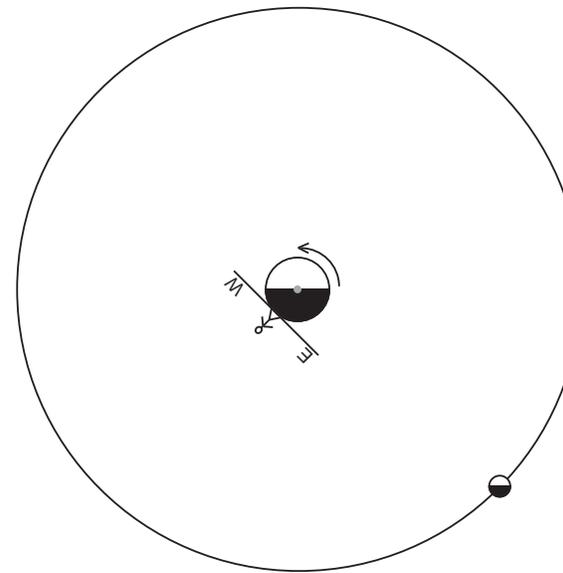
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

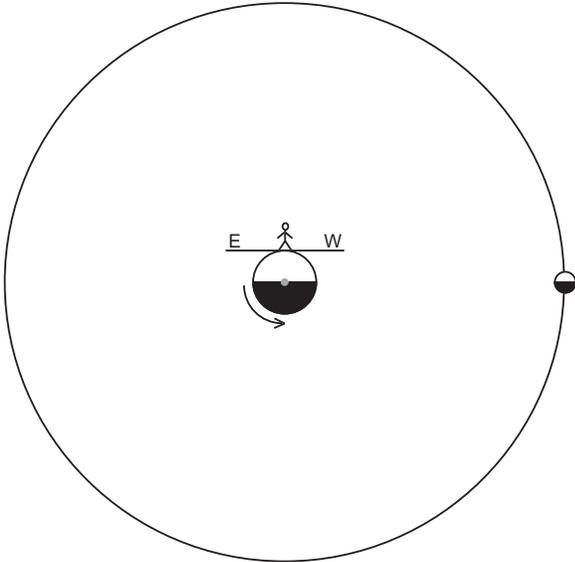
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

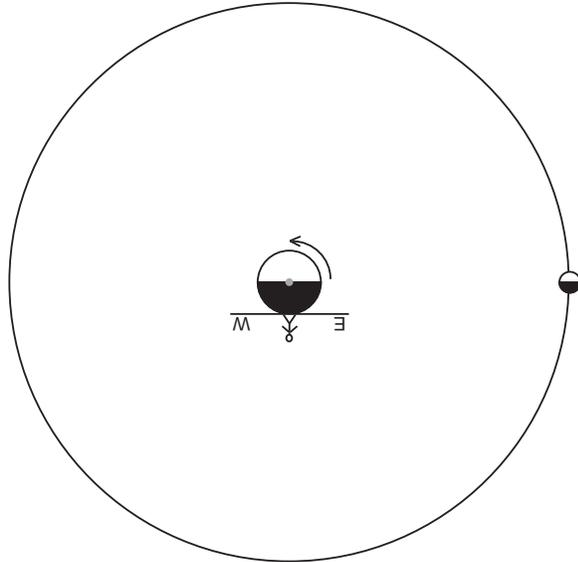
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

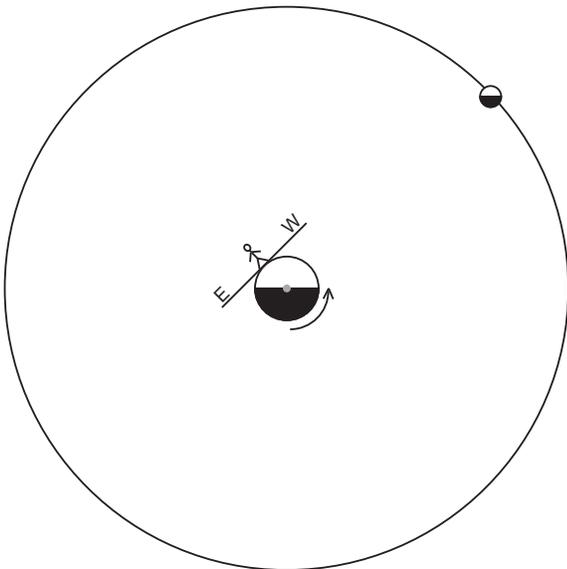
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

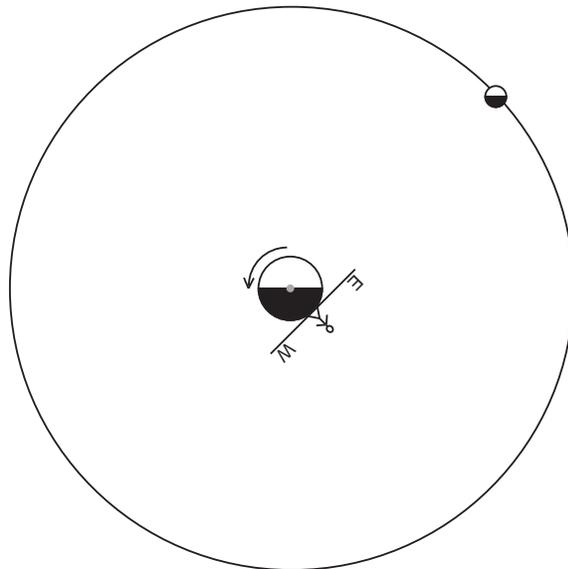
Phase of the moon _____



Moon rise / set

Approximate Time of Day _____

Phase of the moon _____



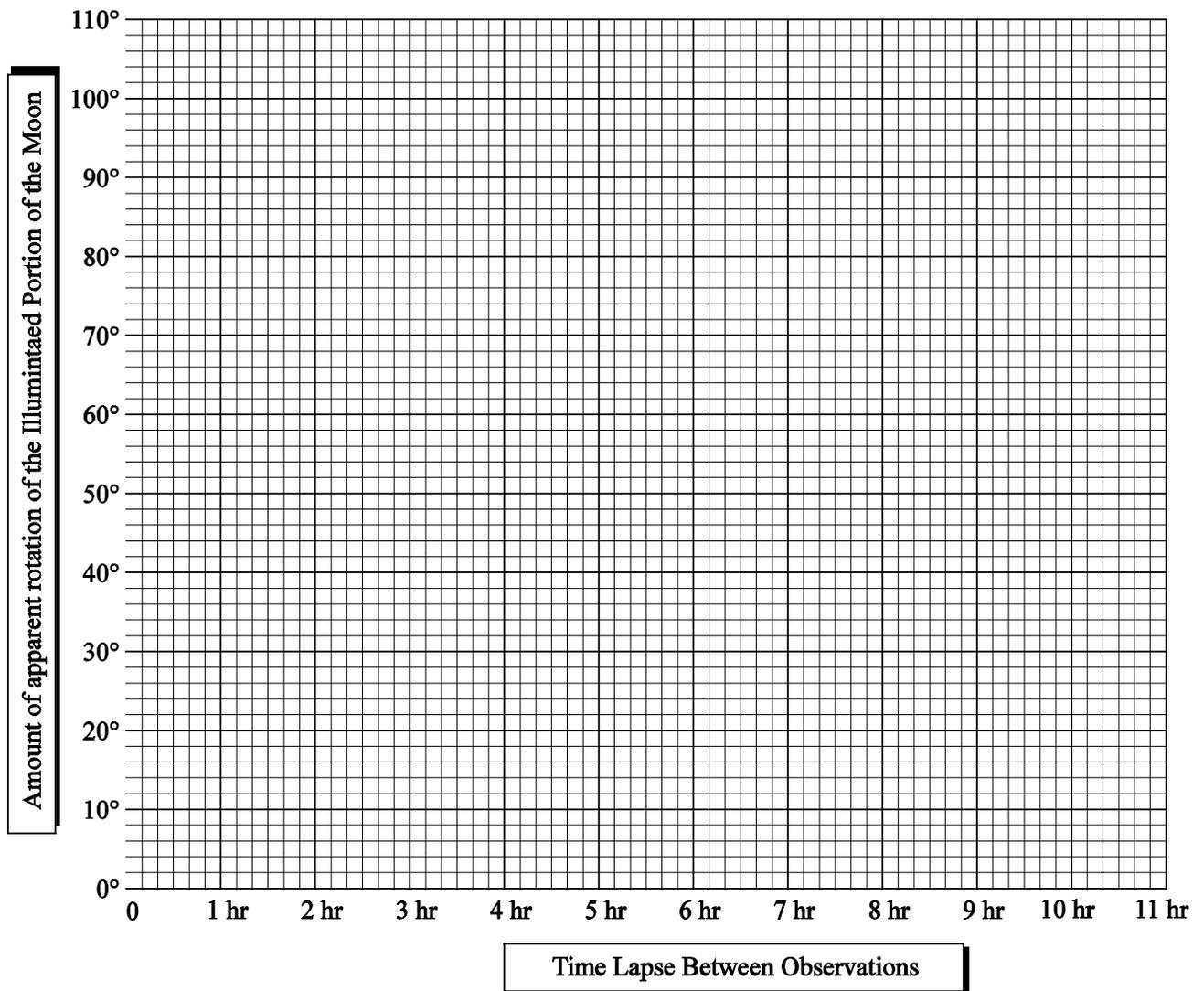
Moon rise / set

Approximate Time of Day _____

Phase of the moon _____

The Moon Project: Topic 2 – Angle of Tilt of the Moon

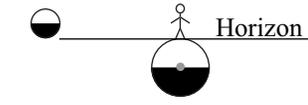
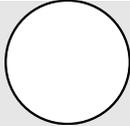
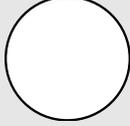
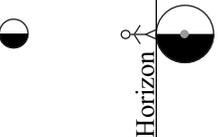
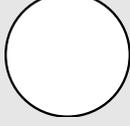
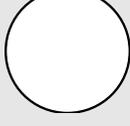
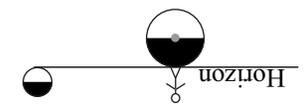
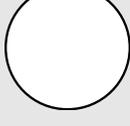
1. As the moon makes its arc across the sky, how many degrees does the lit portion seem to rotate* per hour?
- a. Transfer information from your graphs to the graph below. Use this graph to determine how many degrees per hour the lit portion of the moon seems to rotate (relative to the horizon).



* I do mean *rotate*, not *revolve*. In other words, I mean the change from a hat to a smile, not the movement of the moon across the sky (the Topic 1 folks will worry about that).

2. The angle of the lit portion of the moon relative to the horizon changes. For example, sometimes the crescent moon looks like a crooked smile (☾); other times it looks like a hat cocked at an angle (☾). The lit portion of the moon doesn't really rotate, so why does it look like it does? What is REALLY happening?

- a. Examine the diagrams in the table below. What is the phase of the moon? _____
- b. In each diagram, add an arrow pointing “up” for the person on Earth.
- c. Complete the table, showing what the moon looks like at various times in one “moon day” to a person living at the equator. In each diagram, **you are looking down on Earth’s north pole**. To better see what the moon looks like, look at another person’s handout with the page turned so that the person is “on top” of Earth (Hint: extend the horizon lines; ignore the grid lines of the table.).

Time of day	Location of person living on the equator	Appearance of moon to that person
		 Horizon Line
		 Horizon Line
		 Horizon Line
		 Horizon Line
		 Horizon Line

- d. Explain why, to the person at the equator, the lit portion of the moon seems to rotate relative to the horizon.

- e. We don't live at the equator. We live at 40° north latitude. To show what's happening in Chico, we need to use three-dimensional models; a flat piece of paper won't do.

Materials: Globe

Toy figure, taped onto the globe at Chico (use Post-it tape ONLY)

Piece of cardboard to represent the toy figure's horizon

Polystyrene ball on a pencil, painted half black (to represent the dark side of the moon). Insert the pencil on the line between black and white.

Activity: Complete the table below, modeling each situation.

For example, for the appearance of the first quarter moon at moonrise, hold the ball-on-a-pencil at the same height as the globe and oriented so that a person on the globe would see a 1st quarter moon. Place the globe in position so that the toy figure would see the moon rising. Tilt your head to line up with the toy figure's body and draw what that person would see. To help you visualize this, hold up the piece of cardboard in position to represent the person's horizon (like on the diagrams on the previous page).

Phase	Appearance of moon at moonrise	Appearance of moon at highest point	Appearance of moon at moonset	Direction of apparent rotation
1 st quarter	 Horizon	Horizon	Horizon	
3 rd quarter	Horizon	Horizon	Horizon	
Waxing Crescent	Horizon	Horizon	Horizon	
Waning Crescent	Horizon	Horizon	Horizon	

3. The pattern made by the lunar maria (see Fig. 22.3 on p. 629 of your textbook) is always the same but it is not always at the same orientation—sometimes the “rabbit in the moon” is right side up; sometimes it is upside down. Why does this pattern of lunar maria appear to change orientation?

a. Materials: Globe

Toy figure, taped onto the globe at Chico (use Post-it tape ONLY)

Large photograph of the full moon

Page of small photos of the full moon

Activity: Cut out the small photos of the moon.

Hold the photograph of the moon upright (the top of the photo is the moon’s north pole), facing the globe and at the same height as the globe. As before, turn the globe to model (1) moon rise, (2) the moon at its highest point, and (3) moon set. For each case, glue a small photos of the moon into the appropriate box of the table to show exactly what the moon looks like to a person in Chico.

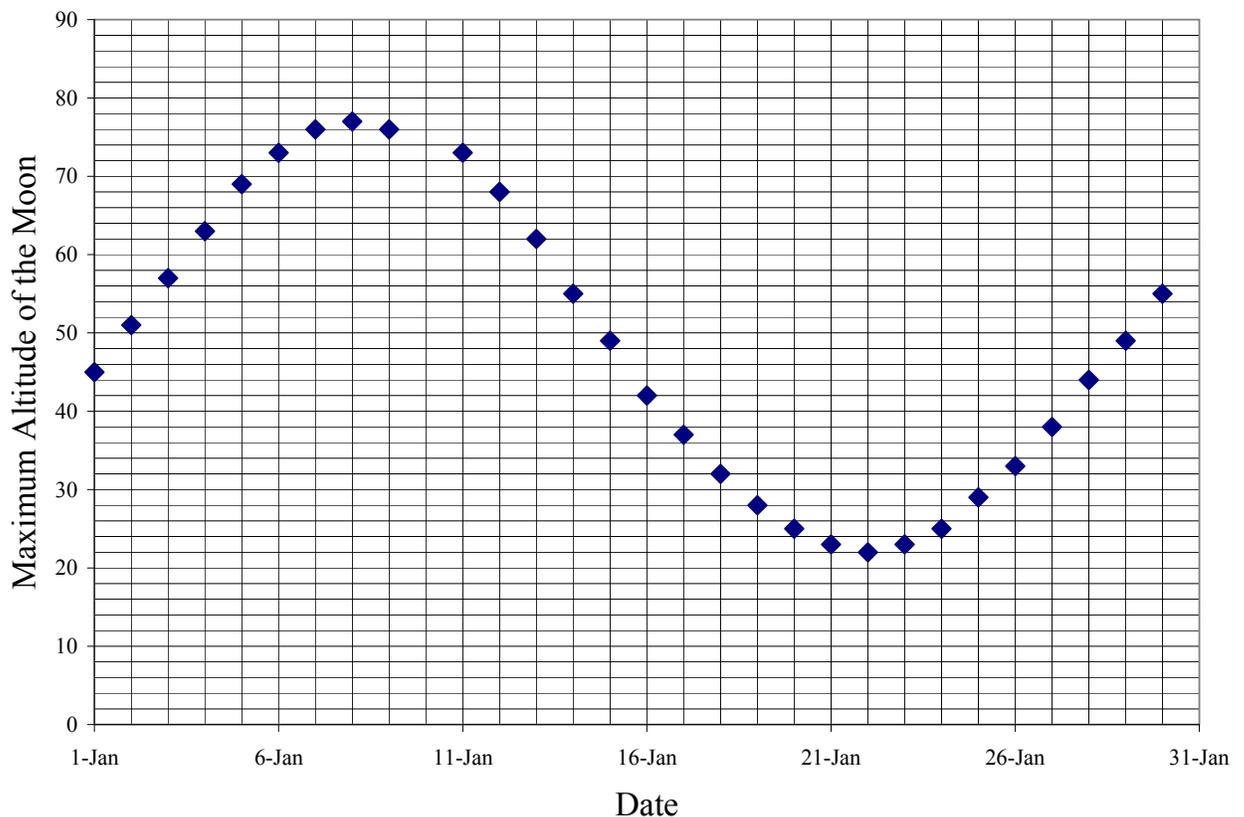
Phase	Appearance of moon at moonrise	Appearance of moon at highest point	Appearance of moon at moonset	Direction of apparent rotation
Full	Horizon	Horizon	Horizon	

Question: Do your observations agree with your completed table above? Show specific examples of your observations that agree or disagree with the table.

Question: Why does the pattern of lunar maria appear to change orientation?

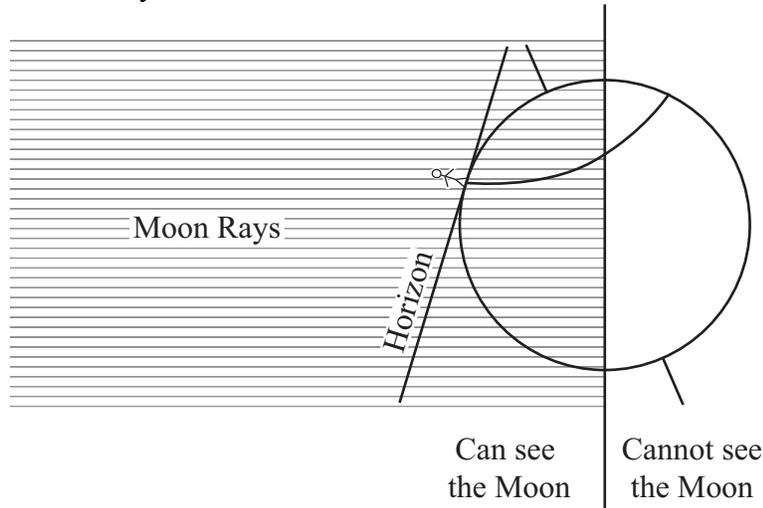
The Moon Project: Topic #3 – Length of the Moon “Day”

1. We all know that the sun is up much longer each day in the summer than it is in the winter. The length of time that the moon is up each “moon day” also varies. Describe how and why the length of the moon day varies over the course of one moon cycle.
2. Every day, the moon follows an arc-shaped path across the sky. It first appears at the horizon, then gradually rises up as it travels across the sky. At the half-way point, the moon reaches a maximum altitude (height above the horizon) for that day. Describe how and why the daily maximum altitude (height of the moon above the horizon) varies over the course of one moon cycle.
 - a. Examine your graph of the number of hours the moon is out. Focus on the part of the graph from the 1st quarter moon in September to the 1st quarter moon in October. Describe how the length of the “moon day” changed over that time period.
 - b. Examine this graph, based on data from <http://aa.usno.navy.mil/>. It shows the maximum altitude of the moon for each day in January, 2009.



Describe any correlations between this graph and your graph of the number of hours the moon is out each day.

- c. Study the diagram below. If we were to add the moon to this diagram, at the correct scale, the moon would be 0.4 inch across and 40 inches past the left edge of this page. At that distance, the rays of light coming from the moon would be lined up parallel to each other as shown by the “moon rays” below.

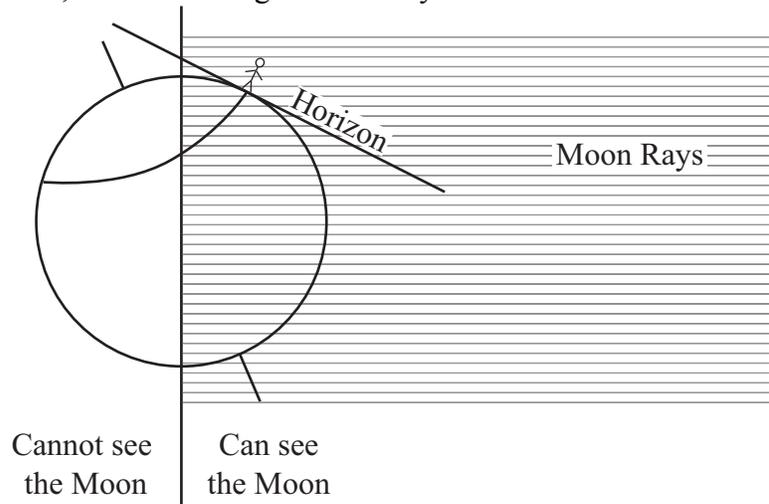


1. The person drawn on Earth is in Chico, viewing the moon at its highest point that day; the moon is in the southern part of the sky. Determine the altitude of the moon in Chico on that day. Explain how you arrived at your answer.

Altitude of the moon: _____

2. The person drawn on Earth completes a full circle around Earth's axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

d. Two weeks later, the moon has gone half way around Earth and is now on the other side.



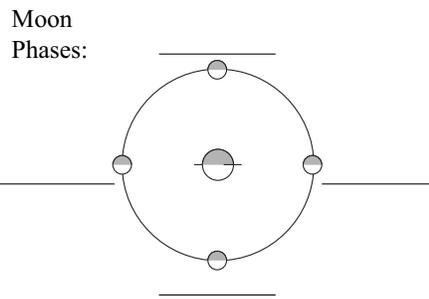
1. The same person is still in Chico. She is viewing the moon at its highest point that day; the moon is in the southern part of the sky. Determine the altitude of the moon in Chico on that day. Explain how you arrived at your answer.

Altitude of the moon: _____

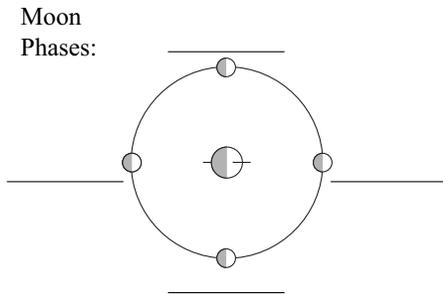
2. The person drawn on Earth completes a full circle around Earth’s axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

e. Why are your answers to parts c and d above so different? What factor determines both the number of hours the moon is out and the maximum altitude of the moon? Explain.

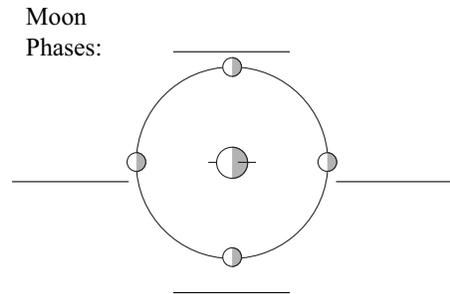
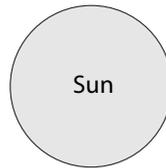
3. The moon is out longest during different phases at different times of the year. There is a definite pattern to the month of the year and which phase of the moon is out longest; clearly and fully describe this pattern and explain why this pattern exists.
4. The maximum daily altitude of the moon varies in a systematic way with regard to moon phase and season. Explain how and why this is true, giving specific examples for each season.
- a. The diagram below shows Earth, tilted toward the right side of the page, in four different positions around the sun. You are looking down on the sun’s North Pole. Add arrows to show the revolution of Earth around the sun and the moon around Earth.
- b. Use a globe, polystyrene ball, and light bulb as needed to help you visualize each situation and complete the diagram. In each “date” blank, enter in the appropriate solstice or equinox.



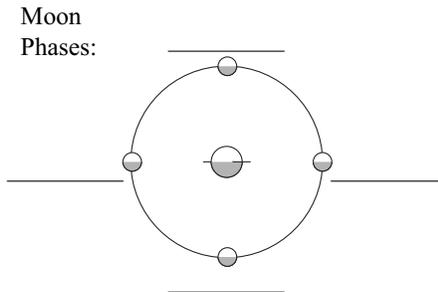
Date: _____



Date: _____



Date: _____



Date: _____

- c. For each position of Earth on the previous page, circle the moon phase that is out the longest.
- d. For each position of Earth on the previous page, explain why that particular moon phase is out the longest.

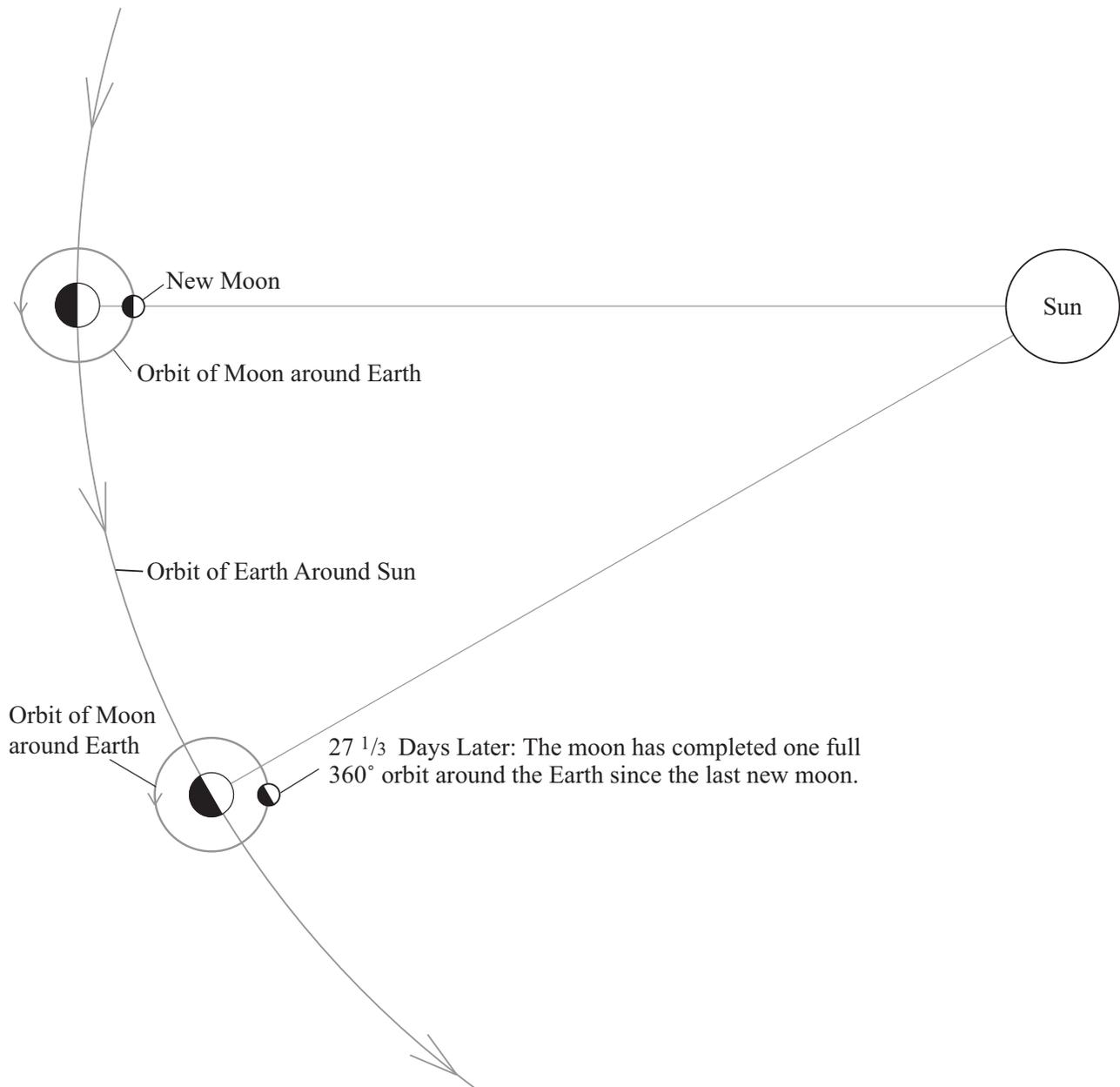
- e. For each position of Earth on the previous page, state which moon phase should have the highest maximum altitude and explain why this is so.

The Moon Project: Topic 4 – Synodic and Sidereal Months

1. The number of hours that the moon is out increases and decreases in a cycle. What is the period of that cycle? One synodic month? One sidereal month? One year? Something else? Why?

- a. **Review of synodic and sidereal months:** A *synodic month* (29.5 days) is the time it takes the moon to go through a complete cycle of phases. A *sidereal month* (27.3 days) is the time it takes the moon to complete a 360° orbit around Earth.

On the diagram below, draw the position of Earth and the moon on the next new moon (Think! Both will have moved!).



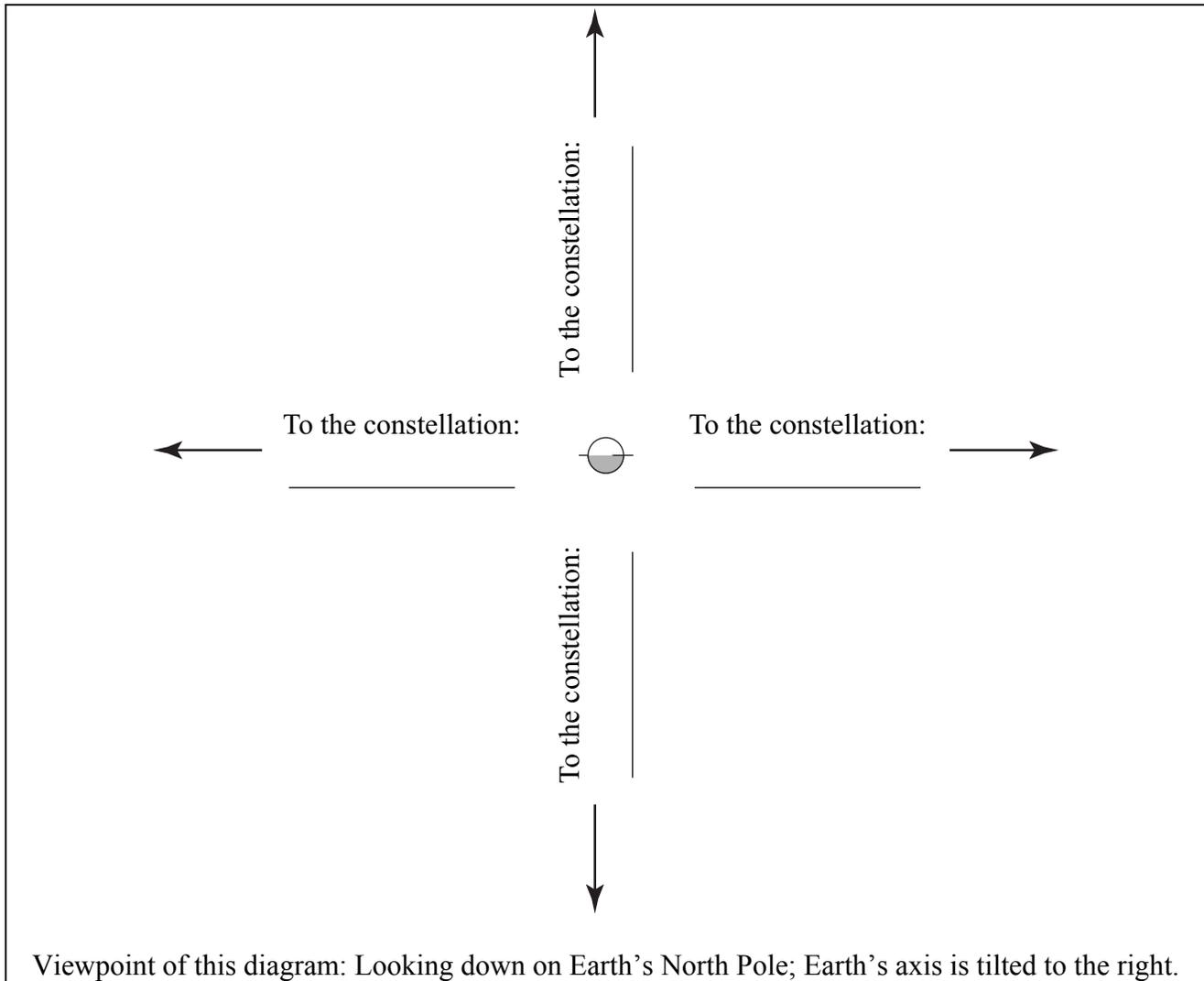
2. What do the longest moon days of all moon cycles have in common? What do the shortest moon days of all moon cycles have in common? What do the average-length moon days of all moon cycles have in common? Why?

- a. Look closely at your graphs showing the number of hours the moon is out each day. You should have written in the place of the moon for each of the longest, shortest and average-length moon days. Complete the table below; the first row has been completed for you.

Month	Astronomical place of the moon on the...			
	Longest Moon Day	Average-length (12.5 hours) moon day—when moon days are getting shorter	Shortest Moon Day	Average-length (12.5 hours) moon day—when moon days are getting longer
January, 2009	Taurus	Leo	Ophiuchus	Aquarius

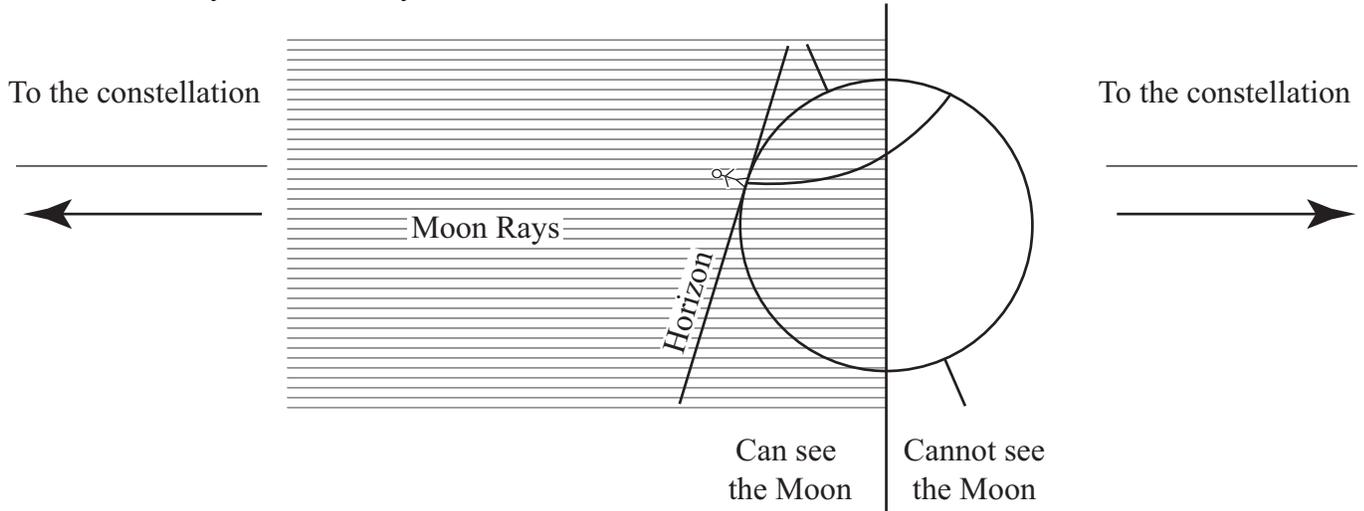
- b. Manipulate the model celestial sphere, using the small yellow ball to represent the moon. Place the moon “in” each of the above constellations. Describe where these key constellations are located relative to each other.

- c. Complete the diagram below, writing the appropriate constellation names in the four blanks provided.



- d. On the diagram above, circle the constellation name that corresponds to the astronomical place of the moon on each of the longest “moon days.”
- e. Which way does Earth tilt, relative to this constellation?

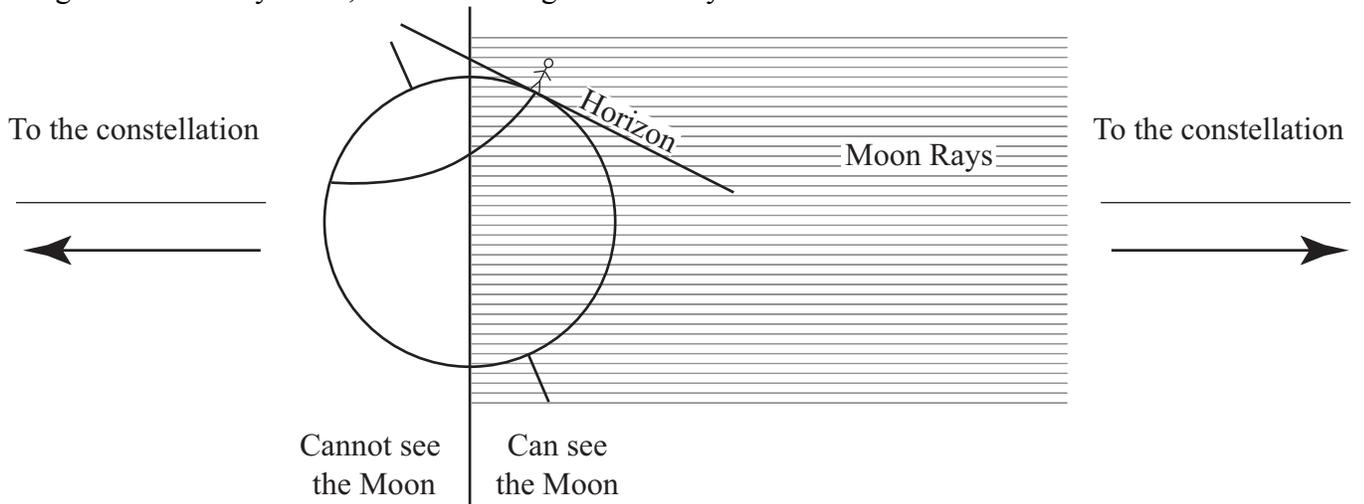
- f. Study the diagram below. If we were to add the moon to this diagram, at the correct scale, the moon would be 0.4 inch across and 40 inches past the left edge of this page. At that distance, the rays of light coming from the moon would be lined up parallel to each other as shown by the “moon rays” below.



1. The person drawn on Earth is in Chico. S/he completes a full circle around Earth’s axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

2. Complete the diagram by writing the correct constellation names in the blanks provided.

- g. Fourteen days later, the moon has gone half way around Earth and is now on the other side.



1. The same person is still in Chico. She still completes a full circle around Earth's axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

2. Complete the diagram by writing the correct constellation names in the blanks provided.
- h. Why is the astronomical place of the moon (approximately) the same on each of the longest, shortest, and average-length moon days? Draw a diagram to illustrate your answer.

3. How long does it take the moon to go through all of the constellations of the Zodiac?
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- a. Closely examine your graph of the astronomical place of the moon for a four-month period. Count the number of days that elapsed between when the moon first entered Sagittarius and, after passing through all of the other Zodiac constellations, when it again entered Sagittarius in October. Repeat for October to November and November to December. Compute the average number of days elapsed.

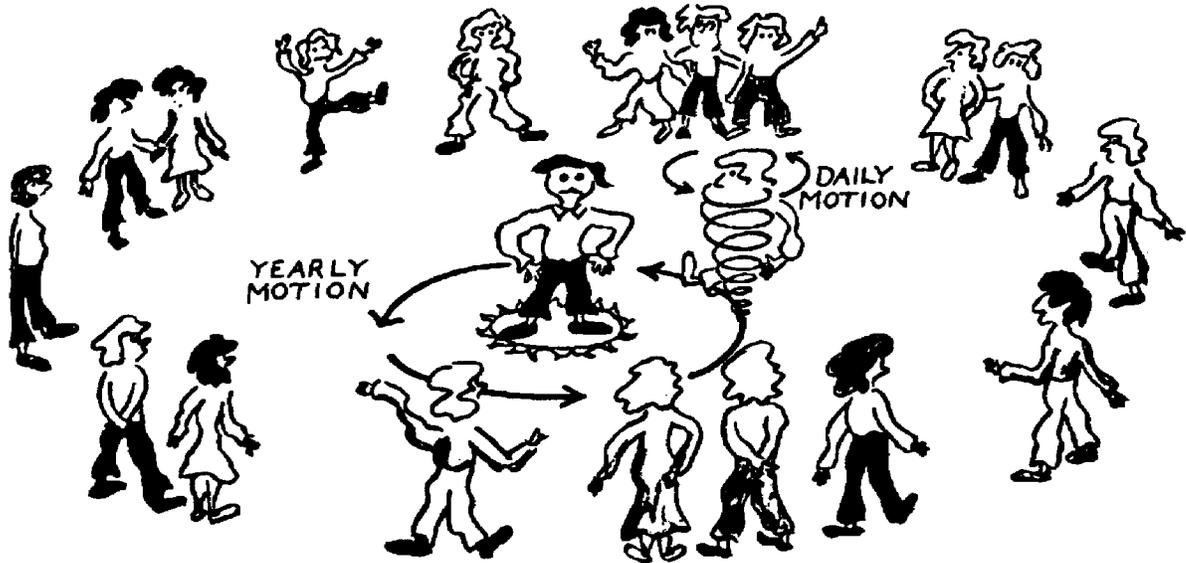
Date when the moon enters Sagittarius	Date when the moon next enters Sagittarius	# of days in between
Average:		

- b. This average is a... (circle the correct answer)

year synodic month sidereal month week day something else

4. How do we know that it takes the moon exactly $27 \frac{1}{3}$ days to complete a 360° orbit of Earth (a sidereal month)?

- a. Model the revolution of the moon around Earth within the context of the background stars any way that works for you. Use the model celestial sphere. Or use a globe and a white ball on a stick. Or do a variation on the outdoor activity we did at the 2nd planetarium visit. But, instead of modeling the sun and Earth (as shown below), model the moon and Earth; or model all three at the same time.



- b. Clearly explain how we know that a sidereal month is exactly $27 \frac{1}{3}$ days.

