Chapter 3

In Class Worksheets & Assignments

Worksheets and assignments begin two pages over

Worksheet next page

3.1 Path of the Sun tutorial

Courtesy of Adams, Prather, Slater, and CAPER Team

Before doing this assignment, you must carefully read section 3.4 of Astronomy Notes! Figure 1 below shows more than half the sky as seen from the continental United States (U.S.). It shows the longest daily path of the Sun on the summer solstice (June 21st) and the shortest daily path on the winter solstice (December 21st). On the summer solstice the Sun reaches the maximum altitude in the southern sky above the horizon at about noon. Notice that the Sun never reaches the zenith (point directly overhead) for any observer in the continental U.S. Over the six months following the summer solstice, the altitude of the Sun at noontime moves progressively lower and lower until the winter solstice. After the winter solstice the noontime Sun altitude moves progressively higher and higher. **Therefore, the winter and summer solstice paths shown below are the lower and upper bounds of the Sun's motion.** For all of the other 363 days of the year, the Sun's daily arc is between the two arc paths shown.

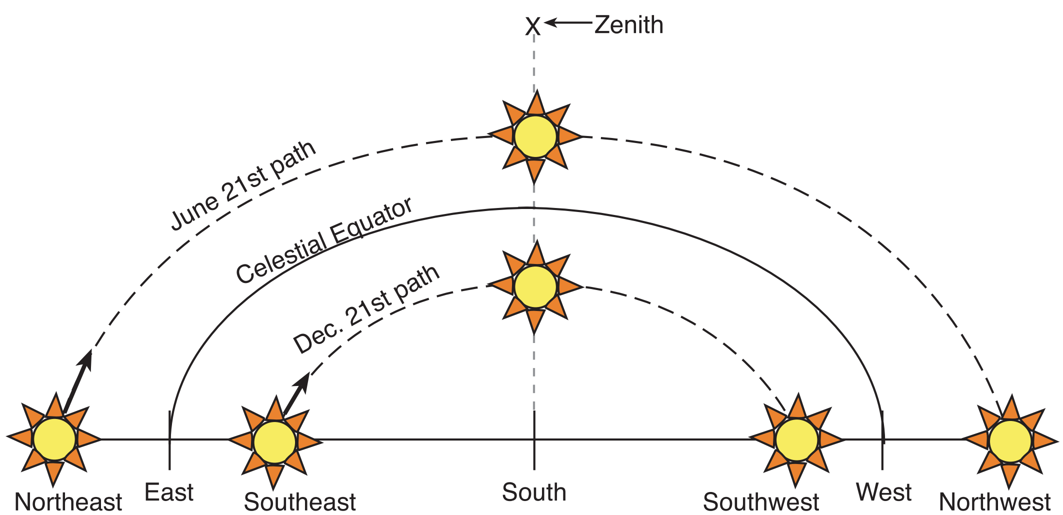


Figure 1

1. According to Figure 1, in which direction would you look to see the Sun when it reaches the highest position in the sky today?

   Circle one: East Southeast South Southwest West

2. If it is wintertime right now (just after the winter solstice), how does the altitude of the Sun at noon change as summer approaches?

   Circle one: increases stays the same decreases
   ——— (arc gets higher) ———— (arc gets lower)

3. If Figure 1 is a reasonable representation for any observer in the continental U.S., is there ever a time of year when the Sun is directly overhead at the zenith (looking straight up) at noontime? If yes, on what date does this occur? (Read that first paragraph again! Do any of the arcs go through the zenith point in the drawing?)

4. During what time(s) of year would the Sun rise:
   (a) north of east?

   (b) south of east?

   (c) directly in the east? (Hint: It is on only which TWO *dates* of the year?)

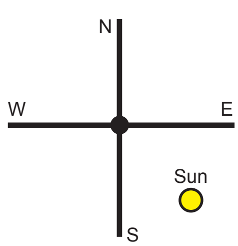
5. Does the Sun always set in precisely the same location throughout the year? If not, tell where the sun will set throughout the year.

6. If the Sun rises south of east on a given day, where will it set on that day?

Shadows are long when the Sun is *low* in the sky and short when the Sun is high in the sky. All shadows everywhere in the universe always point directly away from the light source.

Figure 2 shows a small, vertical stick which casts a shadow while it rests on a large piece of paper or poster-board.

For two different days of the year, the very top of the shadow has been marked with an "x" every hour throughout the day. Although this sketch is somewhat exaggerated, these *shadow plots* indicate how the position of the Sun changes in the sky through the course of these two days. The following questions are designed to show the relationship between Figure 1 above and Figure 2 at right.



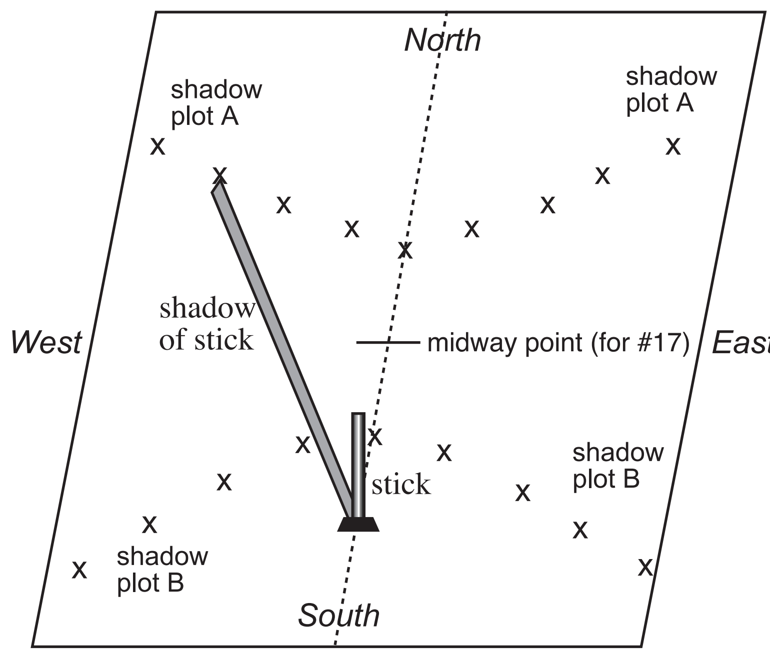


Figure 2

7. Using Figures 1 and 2, in what direction would the shadow of the stick be cast on the poster-board if the Sun rises in the southeast? Remember that any shadow points directly away (or opposite) the light source, so if the Sun is southeast, the shadow points...

   Circle one: West Northwest North Northeast East Southeast

8. Clearly circle *and label* the × for the shadow that corresponds to the time of noon for plot A and for plot B.

   b Are shadows long when the Sun is high in the sky or when the Sun is low in the sky nearer the horizon?

   c As the Sun gets higher in the sky, the shadow lengths _____. (Hint: recall the length of your own body's shadow near sunrise or sunset vs. near noon.)

   Circle one: get shorter stay the same get longer

9. Compare the position of the × that corresponds to noon for shadow plots A and B. Which shadow plot (A or B) goes with a *noon* Sun at its highest position? Explain your reasoning.

10. What do the ×'s in the shadow plots mean? Are they the position of the Sun or the top of the shadow? (Circle which one—look at the figure caption again before answering this.)

11. Which shadow plot has the longer shadows around noon time? Which shadow plot has the shorter shadows around noon time?

12. Which shadow plot (A or B) is most closely *associated with* the Sun's path through the sky during the summer and which is *associated with* the winter? Explain your reasoning. (Does winter have long shadows or short shadows? Does the Sun get high in the sky during the summer or does it stay low?) Make sure your reasoning is logically consistent with #8bc, #9, & #11.

13. On Figure 2, sketch the Sun's position at sun*rise* in the summer AND label the × that the stick's shadow would make at this time.

14. Based on the shadow plots in Figure 2, during which time of the year (summer or winter) does the Sun rise south of east? Explain your reasoning *using shadow lengths and* **directions**. Make sure your reasoning is logically consistent with #7 & #12.

15. If shadow plot A corresponds to the stick's shadow on the day of the winter solstice (double-check answer to #12, #14!), is it possible that there would ever be a time when the stick would cast a shadow longer than the one shown along the north-to-south line that indicates the Sun's position **at noon**? So compare the winter solstice noon shadow with noon shadows at other times of the year. Explain your reasoning. (Hint: Read the bold-face sentence at the top of the first page.)

16. If shadow plot B corresponds to the stick's shadow on the day of the summer solstice (double-check answer to #12, #14!), is it possible that there would ever be a time when the stick would cast a shadow shorter than the one shown along the north-to-south line that indicates the Sun's position **at noon**? So compare the summer solstice noon shadow with noon shadows at other times of the year. Explain your reasoning. (Hint: Read the bold-face sentence at the top of the first page.)

17. Mark the top of the stick's shadow with an × where it should be placed along the north-to-south line to indicate the Sun's position at noon *today*. Clearly explain why you placed the × where you did. (Hint: The equinox noon is exactly midway between plot A's noon and plot B's noon. So is today between the equinox and summer solstice date or is it between the equinox and winter solstice date? THEN answer: is today closer to the equinox or to the solstice date?)

18. Will the stick ever cast a shadow along the north-to-south line that extends to the south of the stick in the continental U.S.? Explain your reasoning. (Hint: Read the bold-face sentence at the top of the first page—is the *noon* Sun ever in the north direction in the continental U.S.?)

19. Is there ever a clear (no clouds and no total solar eclipse) day of the year in the continental U.S. when the stick casts no shadow? If so, when does this occur and where exactly in the sky does the Sun have to be? (Double-check your answer to #3!)

Every 2 / = 0.25; every 1 O = 0.25;
1 O (18 C) ⇒ 4.75, 17 C ⇒ 4.5, 16 C ⇒ 4.25, 15 C ⇒ 4, 14 C ⇒ 3.75, 13 C ⇒ 3.5, 12 C ⇒ 3.25, 11 C ⇒ 3, 10 C ⇒ 2.75, 9 C ⇒ 2.5, etc.

 Name: ___________________________

Sun Position and Time of Day

The Sun rises somewhere in the east (NE-E-SE) and sets somewhere in the west (NW-W-SW). For simplicity, let's assume that the Sun is up for 12 hours and the Sun rises at 6 AM. Fill in the boxes with the time that the Sun is at the positions in the picture below.

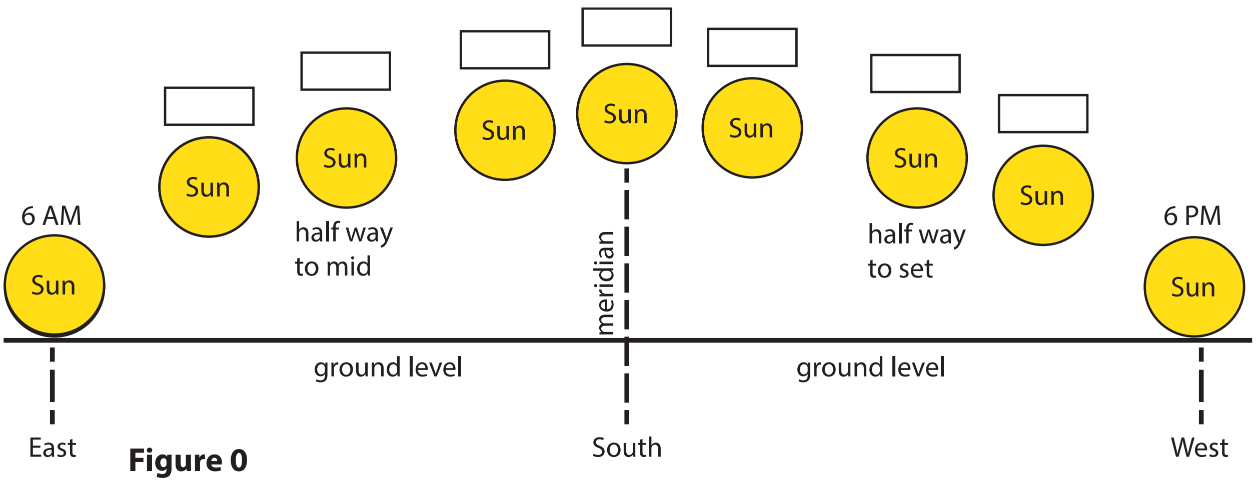


Figure 0

All objects rise somewhere in the east and set somewhere in the west. Objects that cross the meridian up to 12 hours *before* the Sun crosses the meridian (at noon) are "**ahead of**" the Sun (so they rise sometime *between* 6 PM and 6 AM and cross the meridian sometime *between* midnight and noon).

Objects that cross the meridian up to 12 hours *after* the Sun crosses the meridian (at noon) are "**behind**" the Sun (so they rise sometime *between* 6 AM and 6 PM and cross the meridian sometime *between* noon and midnight). For objects A and B, indicate whether they are ahead or behind the Sun. Fill in the box with the time that they would reach the meridian.

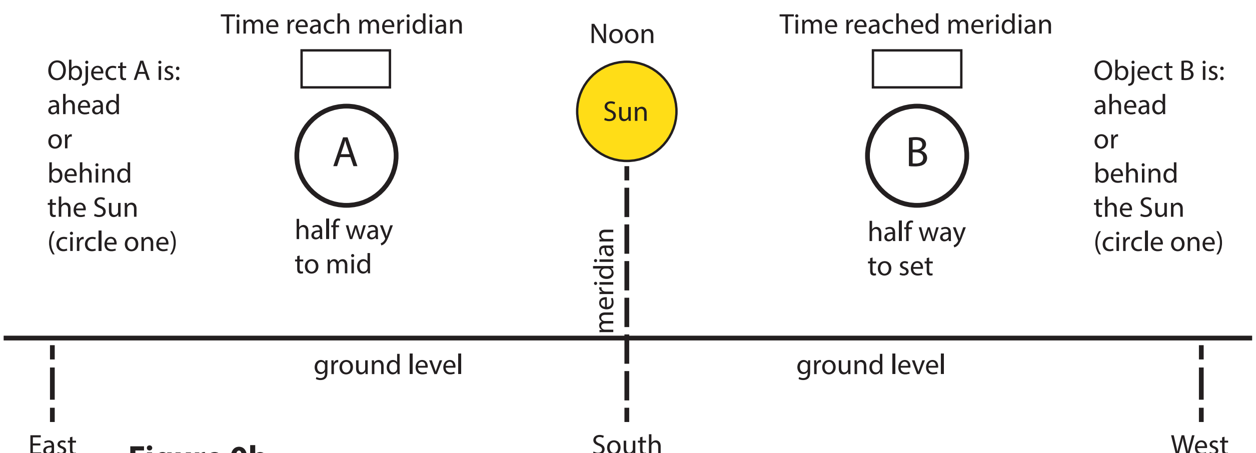


Figure 0b

Lunar Phases Worksheet

Name: ________________________

As the Moon moves around the Earth, we see varying amounts of the lit side of the Moon. When the Moon appears close to the Sun on our sky, we see less of the lit side and more of the night side of the Moon than when the Moon is further from the Sun on our sky. *The larger the angle is between the Sun and the Moon on our sky, the more of the lit (day) side of the Moon we see (the fuller the Moon appears).* In the picture below are various positions of the Moon with respect to the Sun. The time of day is NOON when the Sun is on the **meridian** in the due South direction.

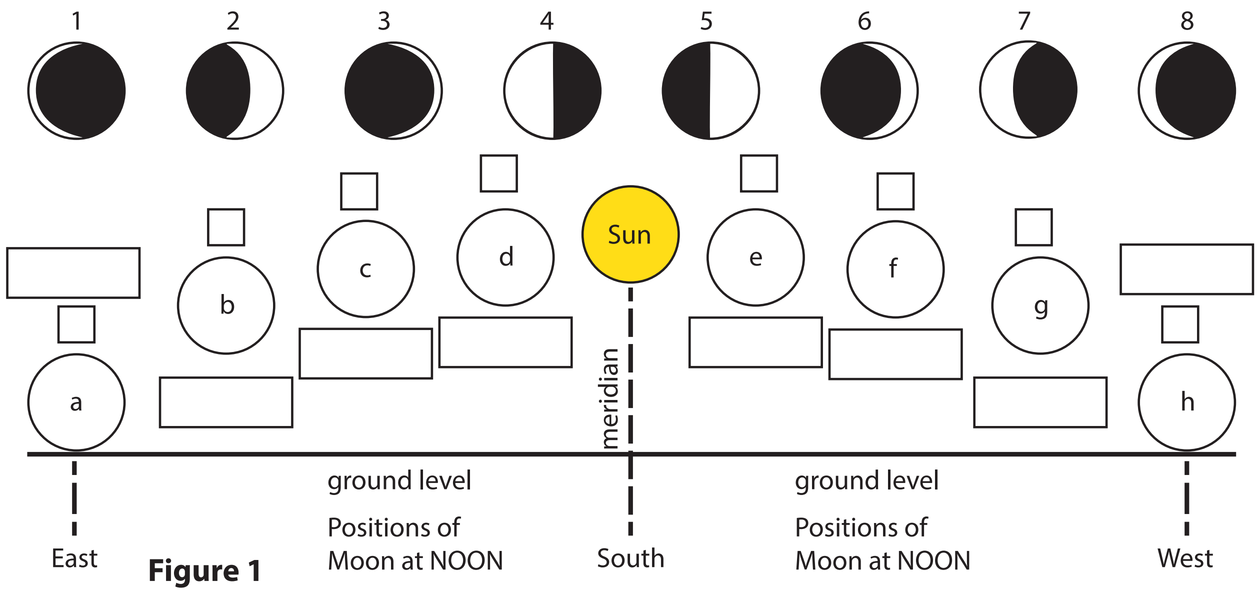


Figure 1

1. Match the phase picture in Figure 1 above with the lettered position (put the phase number in the appropriate square box). Remember that the lit side of the Moon always faces the Sun.
2. The Sun is due South at about Noon. The lettered positions are various phases of the Moon AT NOON. The Earth spins such that objects rise in the east and set in the west. Since the Earth spins 360º in 24 hours, it takes 6 hours to spin 90º, the Sun and Moon will take ***6 hours*** to move from due East to due South (where the meridian is). **Put the time that phase crosses the due South line in the rectangles.**
   a. Does position (h) cross before noon? _________
   b. Choose the correct option for position (h): the Moon is [“ahead of the Sun” // “behind the Sun”] : ___________________
   c. Does position (a) cross before noon? _________
   d. Choose the correct option for position (a): the Moon is [“ahead of the Sun” // “behind the Sun”] : ___________________

Lunar Phases Worksheet Name: ___________________________

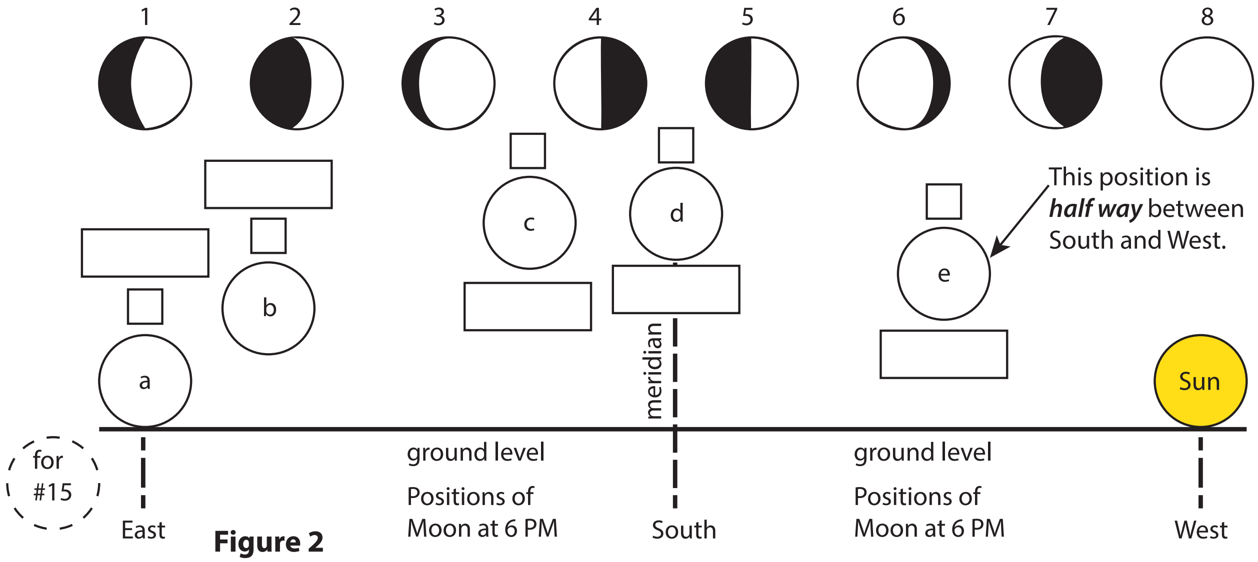


Figure 2

3. Match the phase picture above with the lettered position (put the phase number in the appropriate square box). Remember that the lit side of the Moon always faces the Sun. If a phase picture does not fit a lettered position, then ignore that phase picture (do not try to match).
4. The Sun is due South at about Noon, so Figure 2 above shows the Sun's position 6 hours later (at 6 PM). The lettered positions are various phases of the Moon at 6 PM. Position (e) is half-way between (d) and the Sun. Remember that the 90º angle between East and South corresponds to 6 hours of time. Also, all objects rise in the east and set in the west. **Put the time that phase crosses the due South line in the rectangles.** (All these are "behind the Sun".)

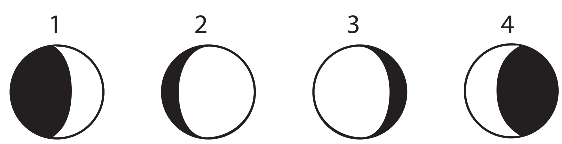


Figure 3

5. In the picture of the four phases above, which phases are *always* near the Sun on our sky = small angle from the Sun?
6. In the picture of the four phases above, which phases are *always* far from the Sun on our sky = large angle from the Sun?

 Name: ________________________

Notice that the larger the angle is between the Sun and the Moon, the more of the daylit side of the Moon we see. Also, notice that the larger is the angle between the Sun and the Moon, the greater is the *difference in time* between when the Sun is due South and when the Moon is due South. Double-check your answers to #1 through #6 and make sure they are logically consistent with these two facts.

7. In Figure 1, what was the time interval between when the Sun was due South and when position (g) was due South (about how many hours between when position (g) was due South and Noon)?

8. Fill in the blank: The waning crescent position (g) is _______ hours ___________ the Sun (choose between "ahead of" or "behind" for the second blank).

9. Figure 4 below shows the positions of a particular waning crescent Moon at various times of the day. Using your answers to #7 and #8, fill in the boxes in Figure 4 with the *time of day* for each of the crescent phases. [Notice that this phase picture would be in position (g) of question #1—if you need to change your answer to #1, do so now.] Remember that it takes the Moon 6 hours to go from due East to due South (along the meridian).

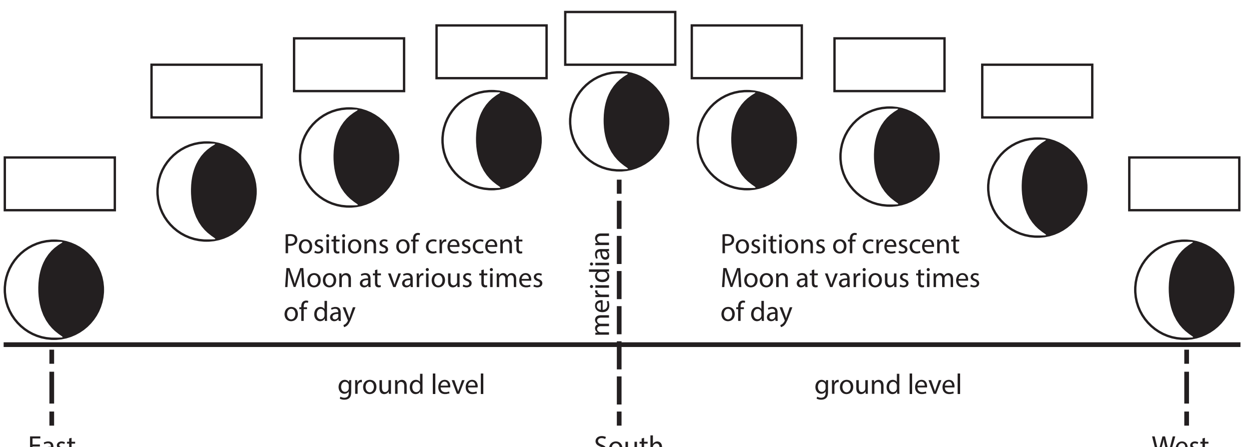


Figure 4

10. Now refer back to Figure 2. What is the time interval between when the Sun was ***due South*** (at Noon on the meridian) and when position (b) was due South (about how many hours)?

11. Fill in the blank: The waxing gibbous position (b) is _______ hours ___________ the Sun (choose between "ahead of" or "behind" for the second blank).

Lunar Phases Worksheet Name: ________________________

12. Figure 5 below shows the positions of a particular waxing gibbous Moon at various times of day. Using your answers to #10 and #11, fill in the boxes in Figure 5 with the *time of day* for each of the gibbous phases. [Notice that this phase picture would be in position (b) of question #3—if you need to change your answer to #3, do so now.] Remember that it takes the Moon 6 hours to go from due East to due South (on the meridian).

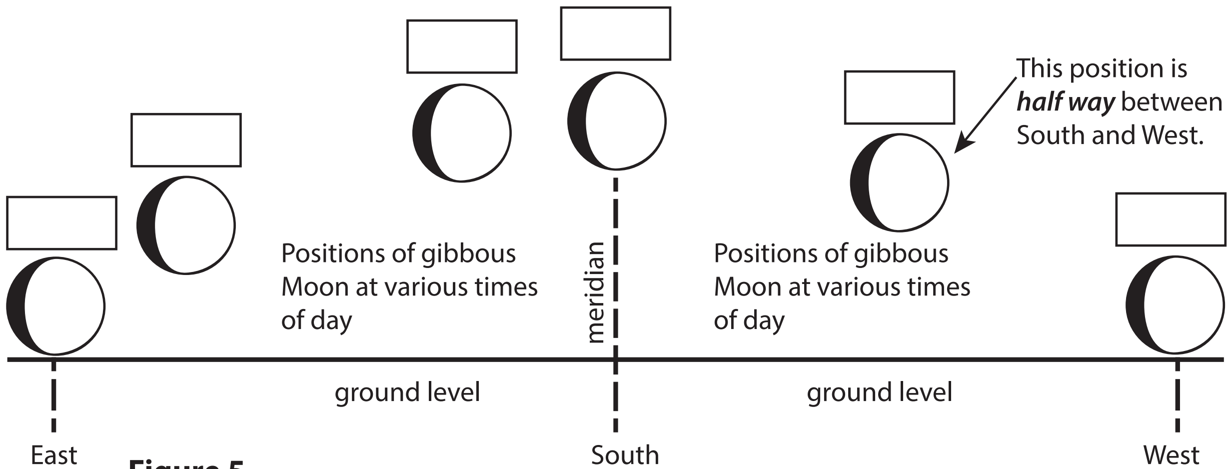
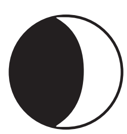


Figure 5

13. In Figure 2, position (e) was close to the Sun, so the Moon phase was a crescent. In question 4, what was the time difference between when the Sun was ***due South*** (at Noon on the meridian) and when position (e) was due South (about how many hours)?

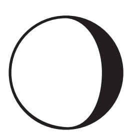
14. The phase picture below shows the waxing crescent phase for position (e) of Figure 2. *Using the pattern of rising & setting motions* of the Moon from the waning crescent and waxing gibbous examples, give the appropriate *time of day* for the given positions.



a. Rising in the east _____________ b. Mid-way up in the west ______________

c. Highest up due south __________ d. Low in the west almost setting _________

15. Now for a totally different phase than what has been given so far. For the phase picture below give the appropriate time of day for the given position. Notice that it is *different* than for Figure 5—this is a *waning* gibbous that would be below the ground in Figure 2.



a. Setting in the west ____________ b. Mid-way up in the west ______________

c. Highest up due south __________ d. Mid-way up in the east _______________

Lunar Phases Worksheet Name: ________________________

Orrery view (space view) to ground view practice

Before doing question #16 and #17, be sure to have reviewed the "Orrery to ground view" example sheets. Here is a view of the Earth and Moon from high above the Earth's north pole.

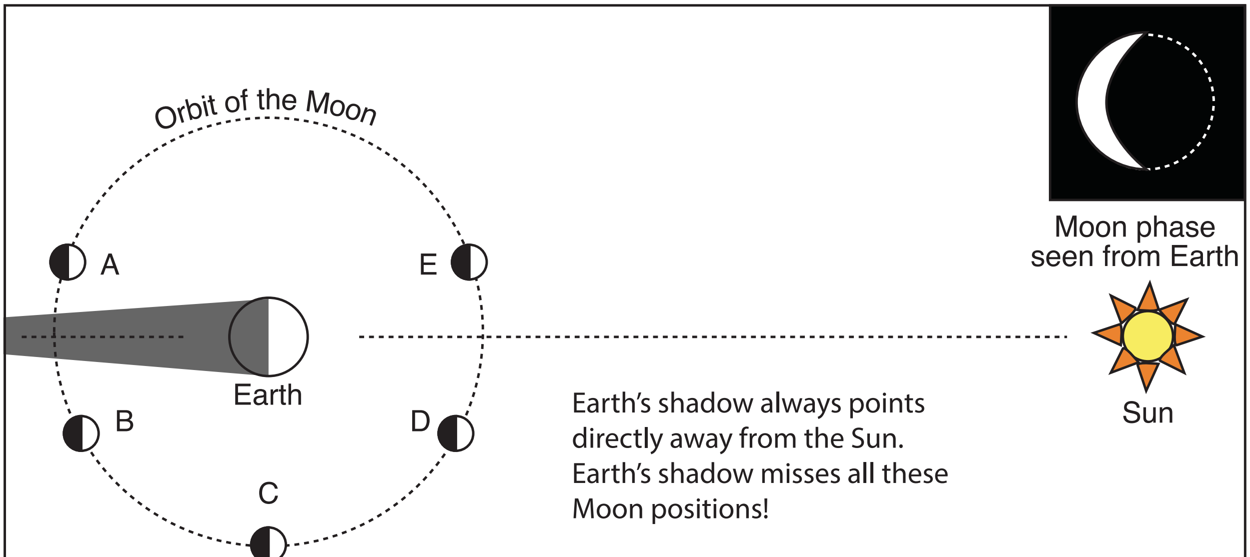
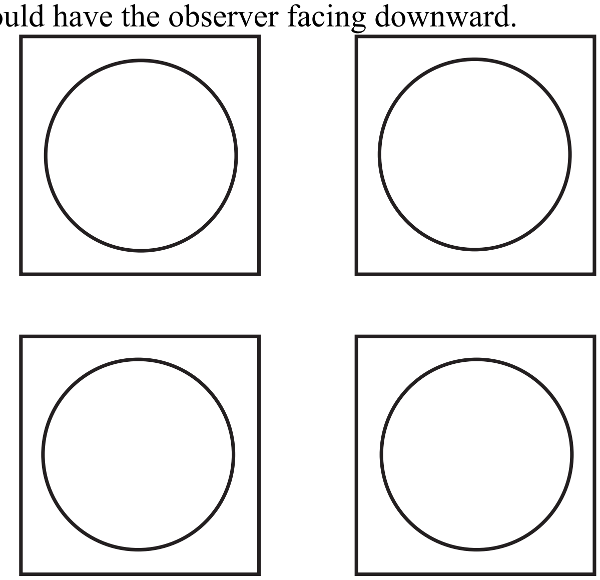


Figure 6

16. Which Moon position (A to E) best corresponds with the moon phase shown in the upper right corner of Figure 6? Make sure that the moon position you choose correctly predicts a moon phase in which only a small crescent of light on the *left*-hand side of the Moon is visible from Earth.
    Enter the letter of your choice: _________

17. In the blank boxes below, sketch how the Moon would *appear from Earth* for the four Moon positions that you did *not* choose in question 16. Be sure to label each sketch with the corresponding letter indicating the Moon's position from the figure above. Note that positions B, C, D would have the observer facing downward.

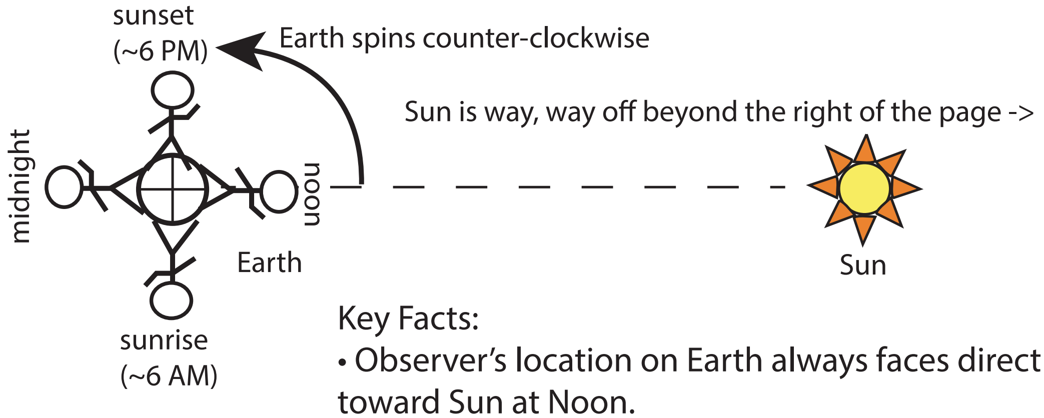
Shade in the part that is dark as seen from the Earth (what we do not see lit).



Lunar Phases Worksheet Name: ________________________

Finding time of day in Orrery view practice

Views of Earth from high above the north pole (so the north pole is in the center of the circle cross hair).



Key Facts:

- Observer's location on Earth always faces directly toward Sun at Noon.
- Observer's location on Earth always faces directly away from Sun at Midnight.
- Earth spins counter-clockwise as viewed from above north pole.
- Observer's location on Earth points due SOUTH toward the meridian at any given time. Meridian (due SOUTH) direction rotates with observer!

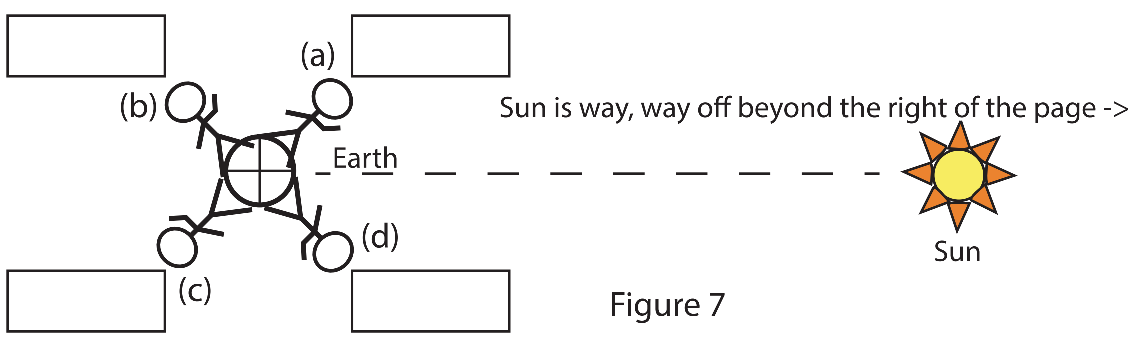


Figure 7

18. Using the Key Facts in Figure 7 above, enter the observer's *time of day* (e.g., noon, 3 PM, 9 AM, etc.) into each corresponding box next to the four observers and answer the following questions with the compass direction the observer's location on Earth is facing at that time Remember that the Earth takes 6 hours to spin 90º. Pay attention to last Key Fact when filling out the compass directions below!

    a. Compass direction observer (a)'s location is facing at 3 PM _______________

    b. Compass direction observer (b)'s location is facing at 9 PM _______________

    c. Compass direction observer (c)'s location is facing at 3 AM _______________

    d. Compass direction observer (d)'s location is facing at 9 AM _______________

 Name: ________________________

Combining Orrery view time of day with Moon phase practice

Views of Earth and Moon from high above the Earth's north pole (so the north pole is in the center of the circle cross hair).

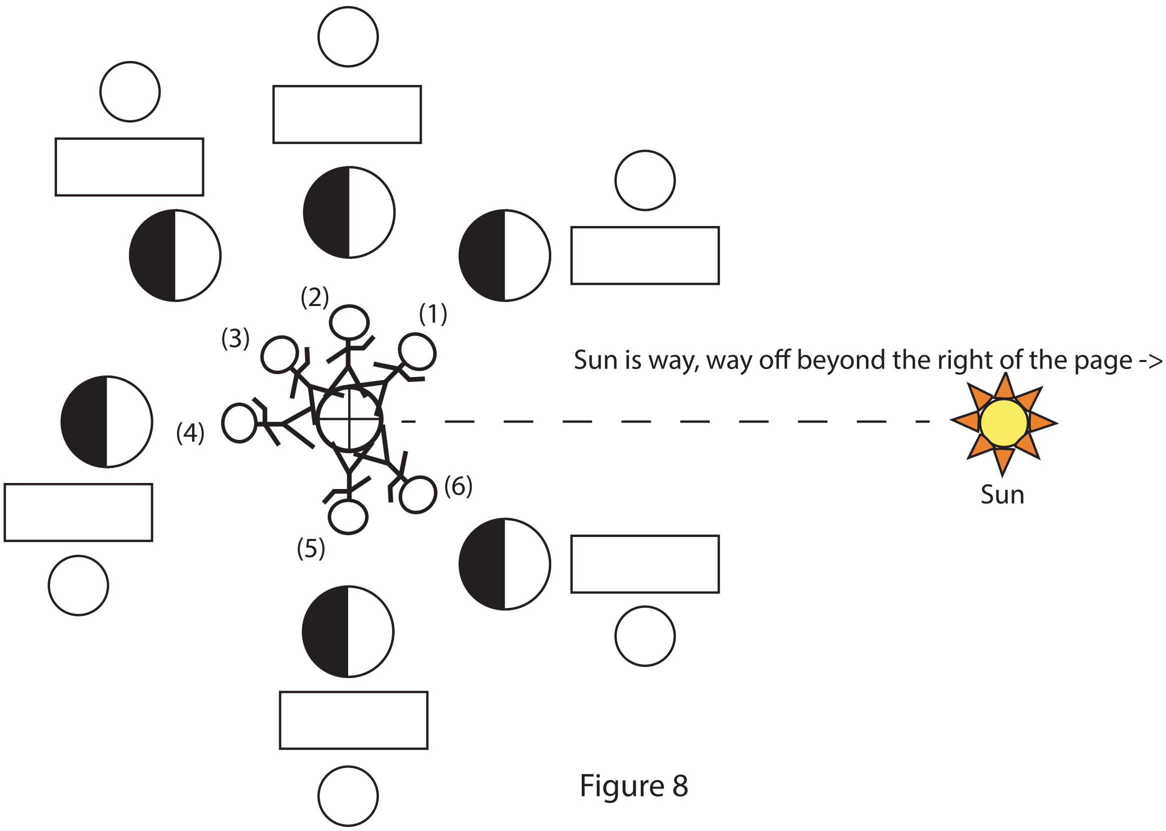
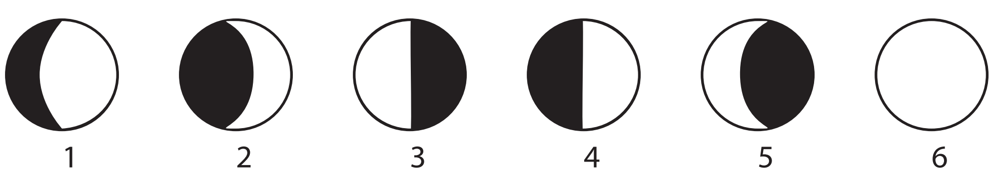


Figure 8

19. Enter the *time of day* (e.g., noon, 3 PM, 9 AM, etc.) each Moon position will be in the due South position into the *BOX* next to each Moon position. Remember that the Earth takes 6 hours to spin 90º. Each observer is facing due South at each particular time of day (SOUTH rotates with the observer). With this Orrery view drawing, you are finding when each Moon phase will be highest up in sky along the meridian!

20. In the figure below are ground view phase drawings: how the Moon appears to us on the Earth. Put the appropriate phase picture number into the *circles* next to the time of day boxes in Figure 8 above.



3.2 Mapping the Solar System from Earth

Courtesy of Adams and Slater and CAPER Team

Learning Group Roles In this in-class project, there are four roles that will be filled by the four students in the group (one student to a role): Leader, Explorer, Skeptic, and Recorder. **These roles are used because, due to limited class time, there is not an opportunity for natural group roles to emerge—stick to your assigned role!** Here is a description of the roles.

Leader: makes sure that each member of the group contributes, that everyone?s ideas are represented, and that the group stays on task to finish the activity in the allotted time.

Explorer: investigates ideas and areas that no one else has considered.

Skeptic: asks the questions, ?Are we sure?? and ?Why do you think that??

Reporter: writes the group consensus answers on the answer sheet and makes sure the assignment is turned in before the class is finished.

Write the names of your team members next to their assigned roles.

Leader: ____

Explorer: ____ — optional role

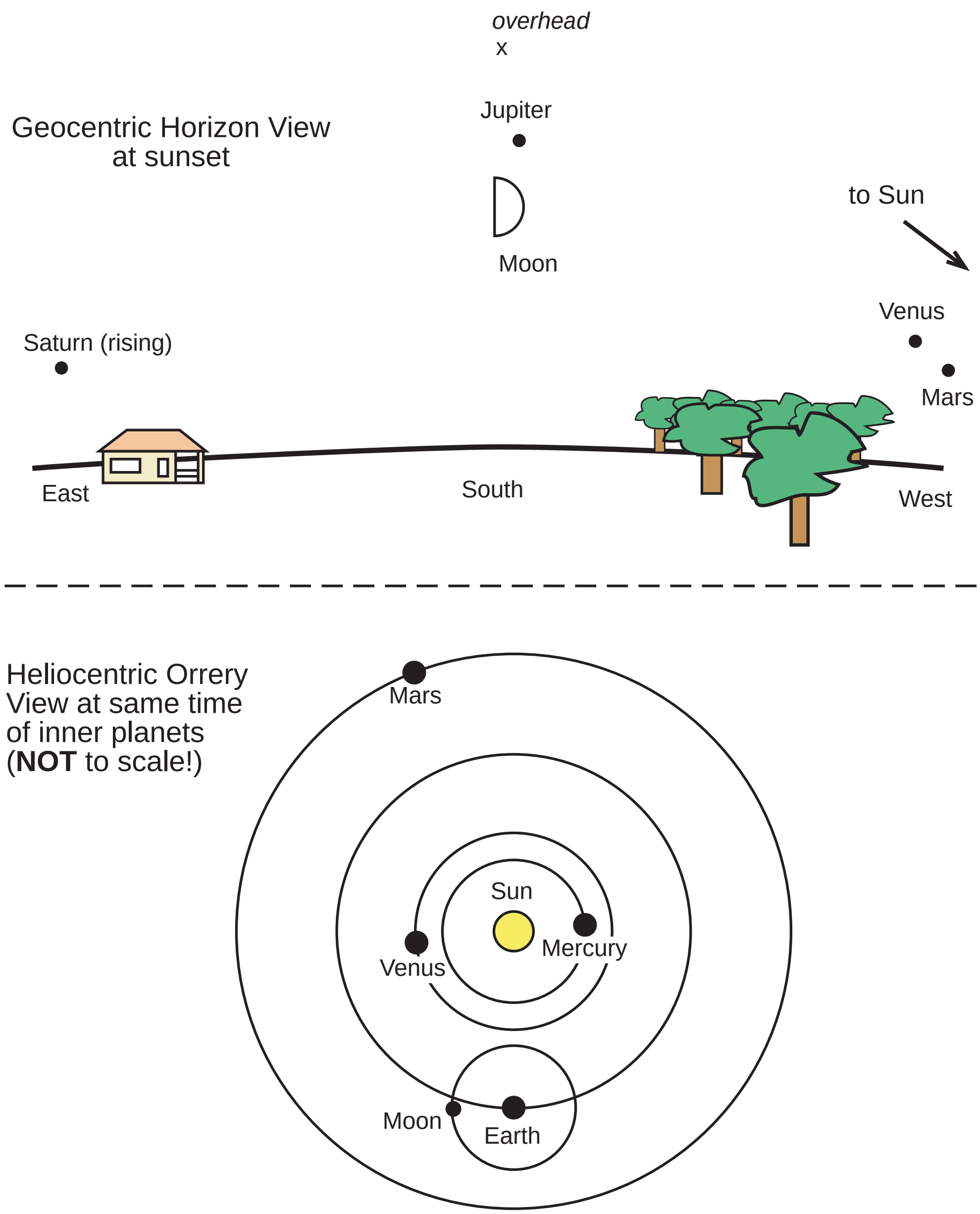
Skeptic: ____

Recorder: ____

Objectives By the end of this activity, you will be able to:

1. Comprehend that the observer's position on Earth make particular objects in the sky visible at specific times.
2. Analyze the rotation of an Earth observer to predict the rising & setting times of sky objects.
3. Synthesize heliocentric object locations and interpret to a geocentric perspective.
4. Synthesize geocentric object positions and interpret to a heliocentric perspective.

Background: Some newspapers and science magazines, such as *Sky and Telescope,* provide sky charts that describe what sky objects are visible at different times. These typically include prominent stars, bright planets, and the Moon. There are two principle maps provided to readers: (1) a geocentric (Earth-centered) horizon view and (2) a heliocentric (Sun-centered) **orrery** view. The **geocentric** perspective is the view from Earth looking up into the southern sky. The **helio-centric** perspective, is the view of the solar system looking down from high above. A drawing of this is called an **orrery**. From above, ALL of the planets orbit and almost all spin counter-clockwise (Venus spins backward). An example appears below.

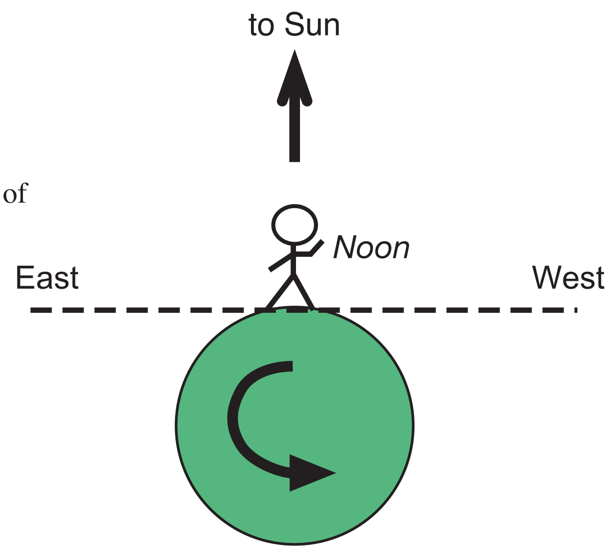


Part I: Rising and Setting Times

As seen from above, Earth appears to rotate counterclockwise. Figure 1-a shows a top view of Earth and an observer and his horizon at noon. Note that our Sun appears at greatest altitude when we are pointed directly toward the Sun (Noon). The horizon rotates counterclockwise. This is a *crucial* diagram that you will refer to in the rest of this assignment!

1. In **Figure 1-a**, sketch and label the positions of the observer and his horizon at midnight, 6 PM (sunset) and 6 AM (sunrise).

Figure 1-a: Observer positions on Earth. (Observer is at Equator)



2. Consider **Figure 1-b**, which shows Earth, Moon, Mars, Mercury, and Venus. At what time would each of these sky objects be highest (on the meridian)? Remember that Earth spins counterclockwise when viewed from above. [*Hint: Make use of Figure 1-a*]

Time Overhead:

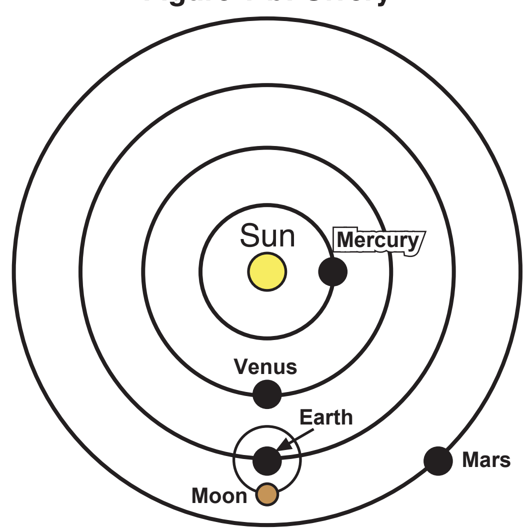
Venus: ___________________________

Moon: ___________________________

Mars: ___________________________

Mercury: _________________________

Figure 1-b: Orrery



Mars and Earth are at exact same vertical position

3. If Earth spins 360° in 24 hours, that means that each sky object is visible for about 12 hours. What time will the sky objects shown in Figure 1-b rise and set? Complete the table below (and refer back to Figure 1-a!). *Each member of your team should fill in the data for one sky object.* 12 AM is midnight, and 12 PM is noon, but use "noon" or "midnight" instead of 12 PM and 12 AM. (Recall that an object is at its highest altitude when it is on the **meridian**.)

Sky Object	***Rise Time***	***Time on Meridian***	***Set Time***
Sun			
Venus			
Moon			
Mars			

4. Using complete sentences, explain why our Sun is not visible at midnight. Add an orrery sketch of Earth, Sun, and observer (as seen from high above the Earth) in the space provided to support your explanation.

Narrative	***Sketch***

Part II: Converting Geocentric to Heliocentric

5. **Figure 2-a** on the next page shows the horizon view of the first quarter Moon and Saturn visible at sunset. On the orrery shown in Figure 2-b, you will sketch and label the position of Jupiter, Moon, and Saturn. (1) First use an arrow to indicate the direction to the Sun in Figure 2-b. (2) After drawing the arrow, indicate the position of the observer at *sunset*. (**Recall** figure 1-a: at NOON, the observer is facing directly toward the Sun and the Earth spins counter-clockwise.) (3) Draw the observer's horizon at sunset. (4) Sketch and label the position of Jupiter, Moon, and Saturn. (**Recall** the observer is pointed directly toward an object if the object is on the observer's meridian—due South.) (5) After completing the diagram, complete the table. 12 AM is midnight, and 12 PM is noon, but use "noon" or "midnight" instead of 12 PM and 12 AM.

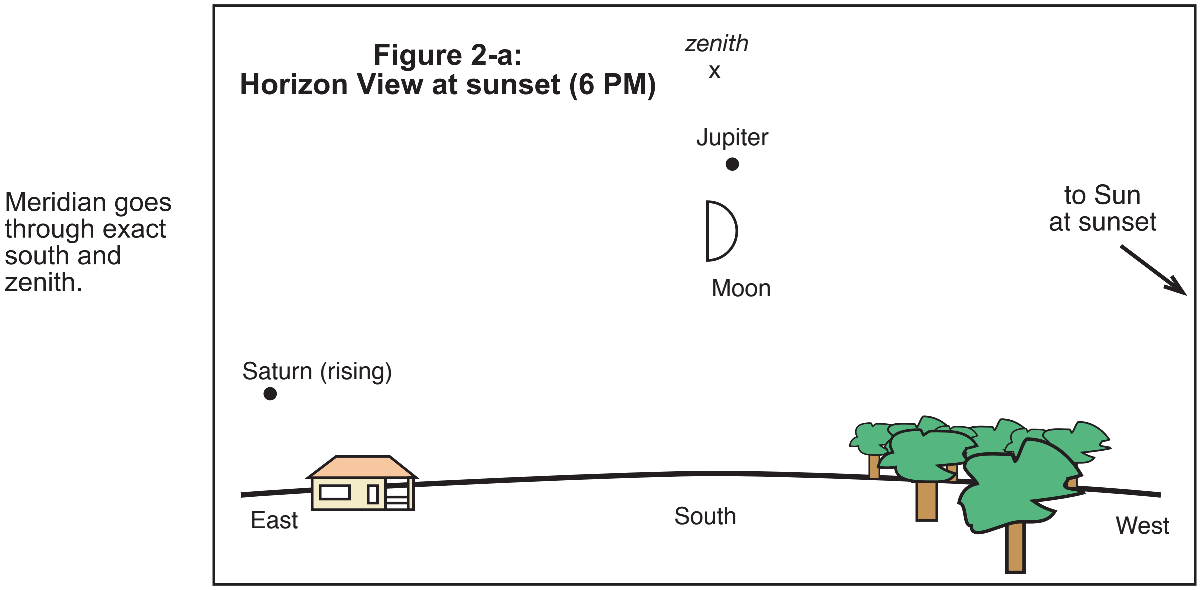


Figure 2-a: Horizon View at sunset (6 PM)

Sky Object	Rise Time	Set Time
Sun		
Jupiter		
Moon		
Saturn		

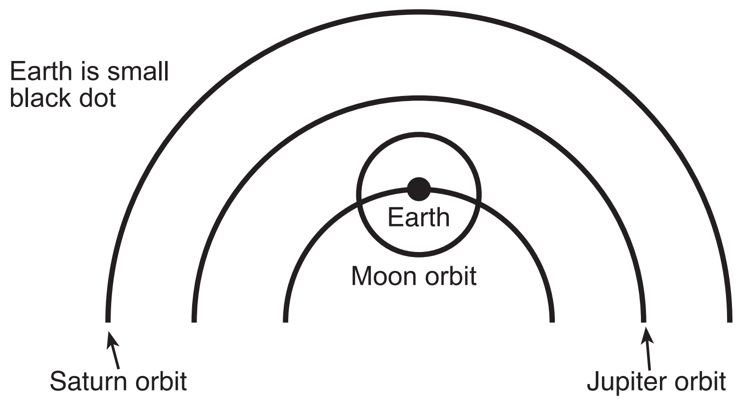


Figure 2-b: Orrery NOT drawn to scale!

6. If Neptune is visible on the meridian in the southern sky at sunrise (6 AM), sketch the relative positions of Sun, Earth, Neptune, and observer with his horizon in an orrery in the space below. (**Recall** figure 1-a: at NOON, the observer is facing directly toward the Sun and the Earth and horizon spins counter-clockwise—so what direction are we facing at 6 AM? Also the observer's part of Earth points toward whatever object is on the meridian.)

Part III: Converting Heliocentric to Geocentric

7. **Figure 3-a** shows the position of Mercury, Venus, Earth, Mars, Moon and a comet in an orrery diagram. On the horizon diagram, **Figure 3-b**, below the dotted line sketch and label the positions of Mercury, Venus, Mars, Moon and the comet at *midnight* as seen from on the ground.. (In Figure 3-a which direction is the observer facing at *midnight*?)

Figure 3-a: Orrery

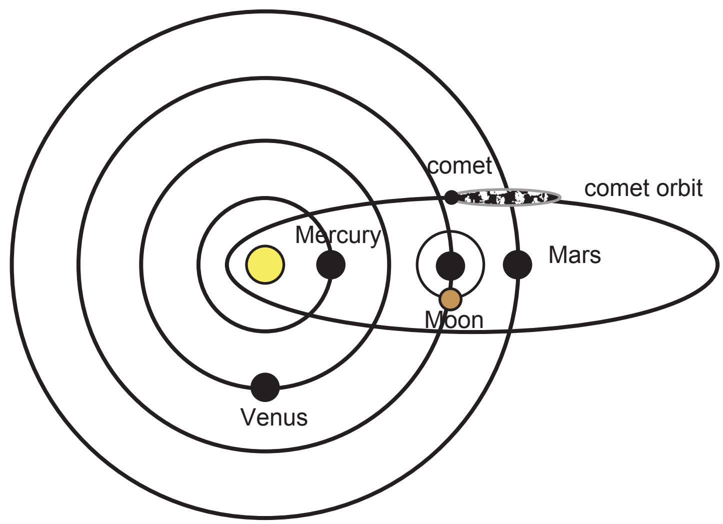
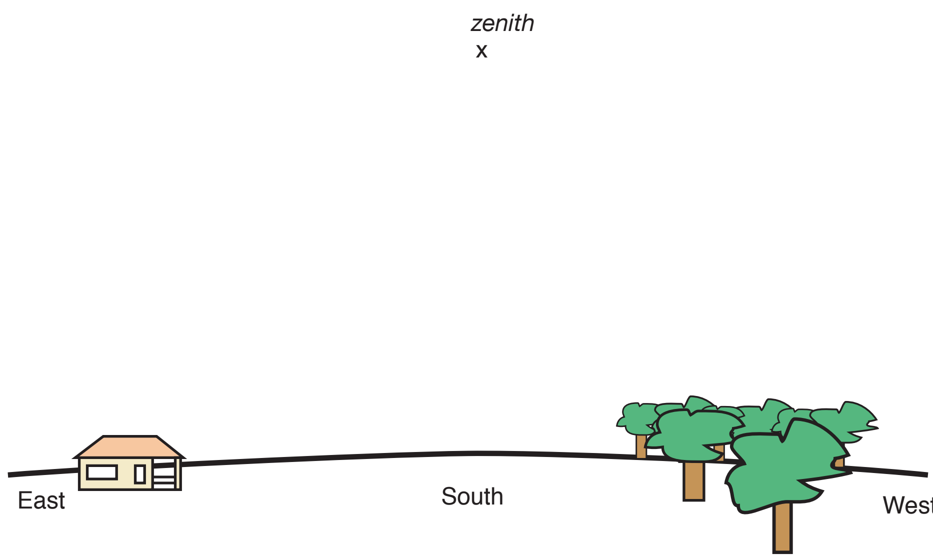


Figure 3-b: Geocentric Horizon View at Midnight

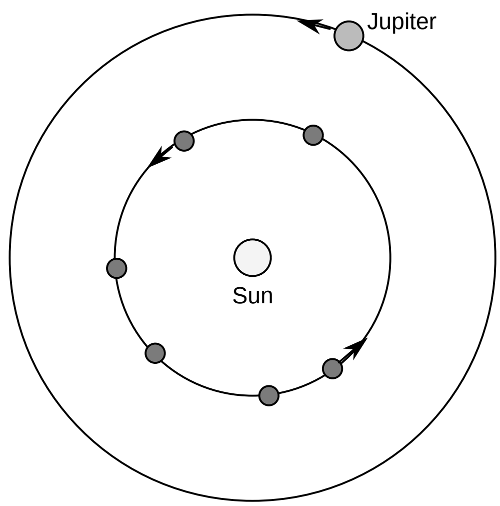


Draw the positions of the objects in the sky as we would see them from on the ground, i.e., translate Figure 3-a to Figure 3-b. If an object is below the ground at midnight, be sure to explicitly say so or draw it and label it below the ground.

8. Venus is often called the *morning star* or *evening star*. Why is it never seen at midnight? Why is it always the case that it is below the horizon at midnight?

3.3 History of Astronomy

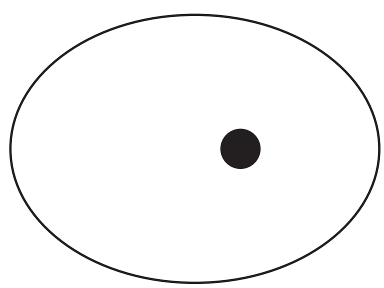
1. (0.5 pt) Circle the position of the Earth that will make Jupiter appear to move in a retrograde loop: (hint: see the retrograde picture in section 4.3.1 of the textbook or concept 26 on exam#1 review sheet.)



2. (0.5 pt) A moon's closest distance to a planet is 300,000 kilometers and its farthest distance is 500,000 kilometers.

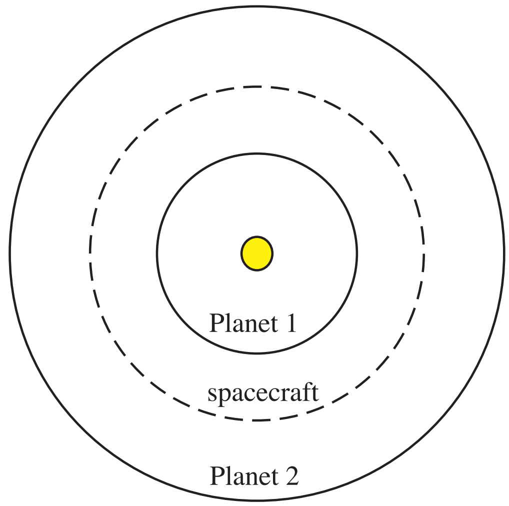
   (a) What is the *semi-major axis* of its elliptical orbit?

   (b) Also, draw the semi-major axis length on the orbit figure below.



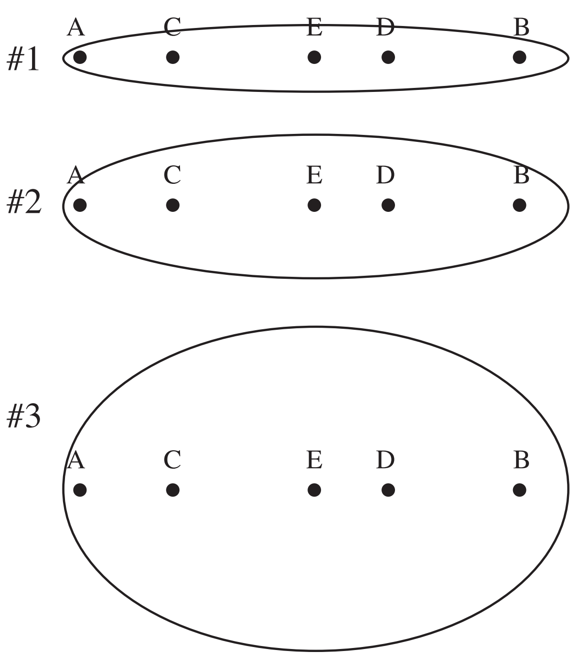
O V E R

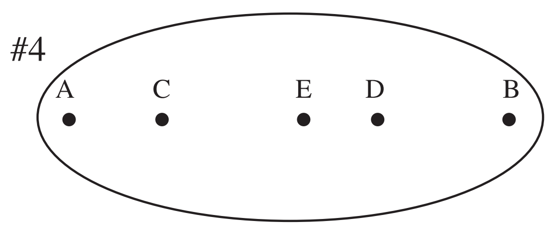
3. (1 pt) NASA wishes to put a satellite into a circular orbit around the Sun with an orbital period of 16 years.



(a) Between which planets will this satellite orbit? Some planet orbital period you will need: Mercury–0.24 years, Venus–0.62 years, Earth–1.0 years, Mars–1.9 years, Jupiter–12 years, Saturn–29 years, Uranus–84 years, Neptune–165 years, Pluto–249 years. (Hint: how does the orbital period depend on distance?)

(b) How far out from the Sun will it orbit? (Hint: use your Kepler's 3rd law graph/table.)





4. (1 pt) **Left column:** Match the focus position with the orbit number. You can use a focus letter only once. Position E is in the center. **Right column:** Match orbit number with the given eccentricity.

orbit #1 ________ 0.9 _______

orbit #2 ________ 0.8 _______

orbit #3 ________ 0.6 _______

orbit #4 ________ 0.45 ______

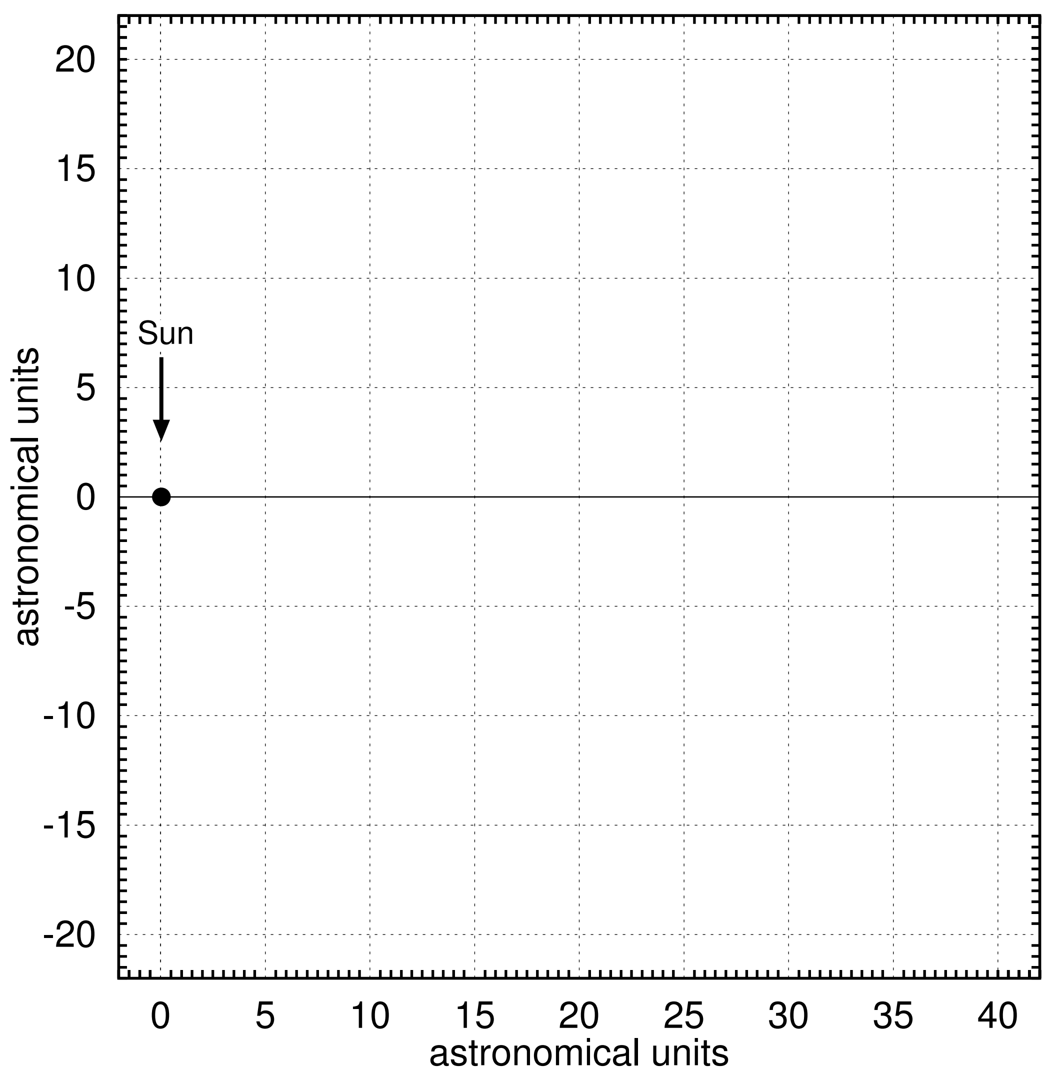
N E X T P A G E

5. (2 pts) A comet has an orbital period of 64 years but approaches within 0.2 A.U. (=1/5 A.U.) of the sun at **perihelion** (this is less than 1 of the small tics in the graph below).

   (a) What is its average distance from the Sun (**semi-major axis** or half-length of its orbit)?

   (b) Since the perihelion is only 0.2 AU, is the eccentricity expected to be closer to 1 or closer to 0? Will it be skinny or fairly circular?

   (c) Using the semi-major value you've found above and the fact that the **minor** axis (full-width) is 5 AU, draw an *accurate* picture of what its orbit looks like on the graph below. Each small tic mark is 0.5 A.U (so is the perihelion more or less than a small tic mark?). The Sun is at the 0,0 point and is *INSIDE* the orbit path. The center of the orbit is a semi-major axis length from one end of the orbit.



Caution: 0.2 AU is less than one tic mark; semi-major axis is *half* the length.

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3.4 Orbital Period and Orbital Distance tutorial

Courtesy of Adams, Prather, Slater and CAPER Team

In this activity you will investigate the relationship between how long it takes a planet to orbit a star (**orbital period**) and how far away that planet is from the star (**orbital distance**). You will start by investigating an imaginary planetary system that has an average star like the Sun at the center. A huge Jupiter-like, Jovian planet named Moto orbits close to the star, while a small Earth-like, terrestrial planet named Spec is in a far away orbit around the star. Use this information when answering the next four questions. If you're not sure of the correct answers to questions 1 – 4, just take a guess. You'll return to these questions later in this activity.

1. Which of the two planets (Moto or Spec) do you think will move around the central star in the least amount of time? Why? *It might help to draw a picture of the planets and orbits.*

2. If Moto and Spec were to switch positions (so that Moto is now farthest), would your answer to question 1 change? If so, how? If not, why not?

3. Do you think the orbital period (= orbit time) for Moto would increase, decrease, or stay the same if it were to move from being close to the central star to being much farther away? Why?

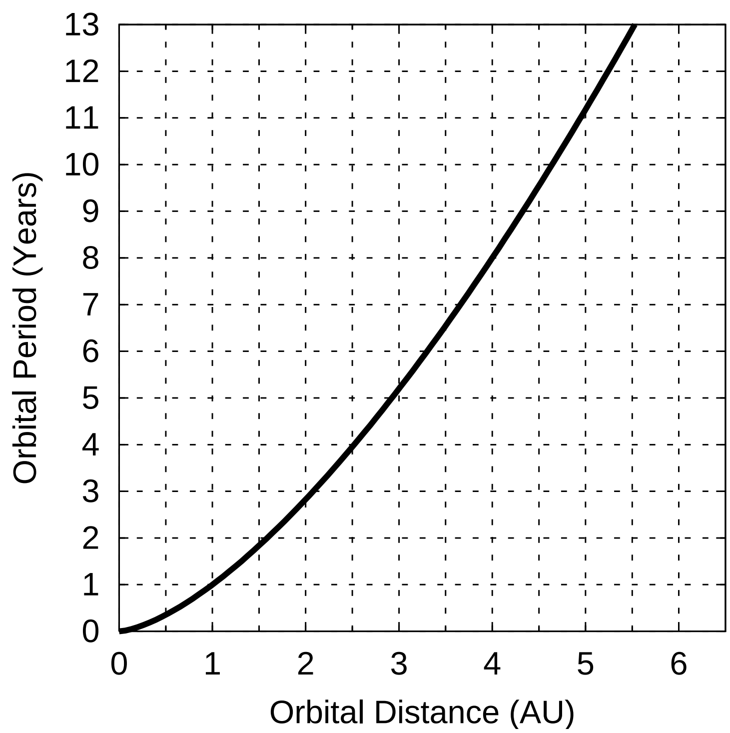
4. Imagine both Moto and Spec were in circular orbits around the central star at the same distance from the star. Do you think the two planets would have the same or different orbital periods? Why?

The graph below illustrates how the orbital period (expressed in years) and orbital distance (expressed in Astronomical Unites, AU) of a planet orbiting a Sun-mass star are related.

5. According to the graph, would you say that a planet's orbital period appears to increase, decrease, or stay the same as a planet's orbital distance is increased?

6. How far from the central star does a planet orbit if it has an orbital period of 1 year?

7. How long does it take a planet to complete one orbit if it is twice the distance from the central star as the planet described in question 6?



8. Based on your results from questions 6 and 7, which of the following best describes how a planet's orbital period will change (if at all) when its distance to the central star is doubled? Circle your choice. (Compare 1 AU orbit period with 2 AU orbit period.)
   (a) The planet's orbital period will decrease by more than half.
   (b) The planet's orbital period will decrease by half.
   (c) The planet's orbital period will not change.
   (d) The planet's orbital period will double.
   (e) The planet's orbital period will more than double.

9. Which of the following best describes how a planet's orbital period will change (if at all) when its distance to the central star is TRIPLED? Circle your choice. (Compare 1 AU orbit period with 3 AU orbit period.)
   (a) The planet's orbital period will be less than one-third as long.
   (b) The planet's orbital period will be one-third as long.
   (c) The planet's orbital period will not change.
   (d) The planet's orbital period will be three times longer.
   (e) The planet's orbital period will be more than three times longer.

In the table below you are provided with the orbital distances, orbital periods and masses for the six planets closest to the Sun.

Planet	**Orbital Distance (in Astronomical Units, AU)**	**Orbital Period (in Years)**	**Planet mass (in units of Earth's mass)**
Mercury	0.38	0.24	0.06
Venus	0.72	0.61	0.82
Earth	1.0	1.0	1.0
Mars	1.52	1.88	0.11
Jupiter	5.20	11.86	318
Saturn	9.54	29.46	95.2

10. What is the name of the planet that you identified the orbital distance for in question 6?

11. Consider the information provided in the table and on the graph and choose the answer below that best describes the effect that a planet's mass has on its orbital period. Circle your choice.

    (a) Planets that have small masses have longer orbital periods than planets with large masses.

    (b) Planets with the same mass will also have the same orbital period.

    (c) Planet that have large masses have longer orbital periods than planets with small masses.

    (d) A planet's mass does not affect the orbital period of a planet.

    Explain your reasoning and cite a specific example using at least THREE planets from the table to support your choice. Look at ALL of the planet values—make sure your reason fits ALL of the planets in the table!

12. Review your answers to questions 1 – 4. Do you still agree with the answers you provided? If not, cross out (not erase) your old answer and then describe (next to your original crossed-out answers) how you would change the answers you gave initially.

Every 2 / = 0.25; every 1 O = 0.25;
1 O = 11 C⇒ 2.75, 2 O = 10 C ⇒ 2.5, 3 O = 9 C ⇒ 2.25, etc.

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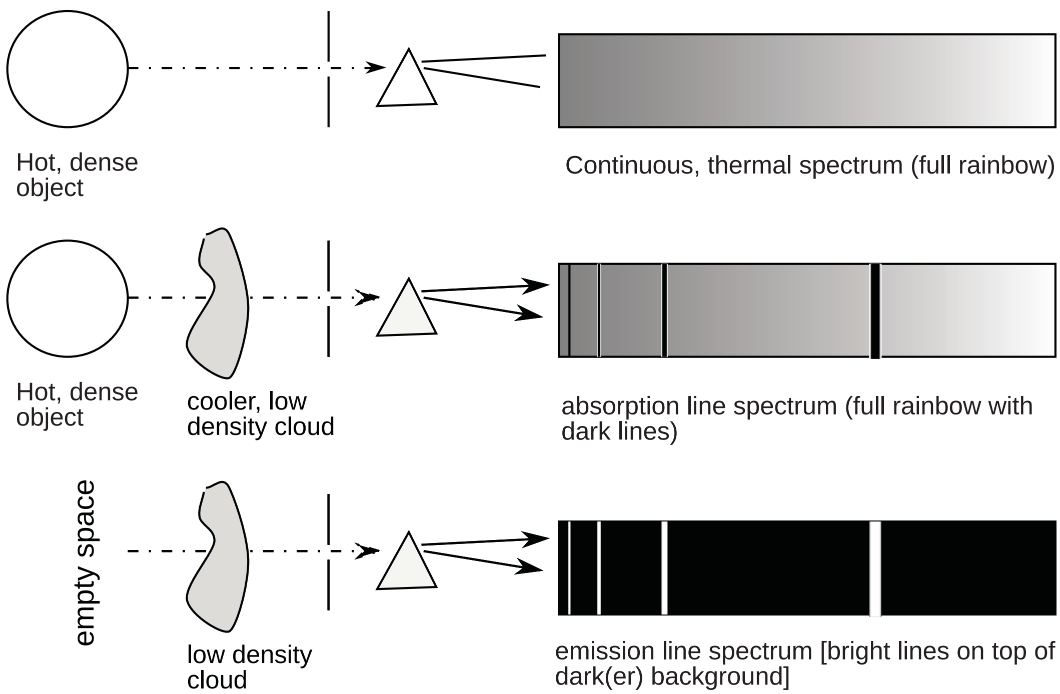
3.5 Types of Spectra tutorial

Courtesy of Adams, Prather, Slater, and CAPER Team



1. What type of spectrum is produced when the light emitted directly from a hot, dense object passes through a spectrometer?

2. What type of spectrum is produced when the light emitted directly from a low density cloud passes through a spectrometer?

3. Describe in detail two things: (a) the SOURCE of light and
(b) the PATH the light must take from the light source to produce an absorption line spectrum.

4. There are dark lines in the absorption line spectrum that represent missing light. What happened to this light that is missing from the absorption line spectrum?

5. Stars like our Sun have cooler, low density, gaseous atmospheres surrounding their very hot, dense cores. If you were looking at the Sun's (or any star's) spectrum, which of the three types of spectra would be observed? Explain your reasoning.

6. If a star existed that was only a hot dense core and did NOT have a low density atmosphere surrounding it, what type of spectrum would you expect this particular star to produce?

7. Two students are looking at a brightly lit full moon, illuminated by reflected light from the Sun. Consider the following discussion between the two students about what the spectrum of moonlight would look like. The Moon has no atmosphere.

Student 1: *I think moonlight is just reflected sunlight, so we will see the Sun's absorption line spectrum.*

Student 2: *I disagree. An absorption line spectrum has to come from a hot dense object. Since the Moon is not a hot dense object it can't give off an absorption line spectrum.*

Do you agree or disagree with either or both of the students? Why?

8. Imagine that you are looking at two different spectra of the Sun. Spectrum #1 is obtained using a telescope that is in space far above Earth's atmosphere. Spectrum #2 is obtained using a telescope located on the surface of the Earth. Label each spectrum below as either Spectrum #1 or Spectrum #2.

Spectrum # _____

Spectrum # _____

(a) Explain the reasoning behind your choices:

(b) Would your answer change if the *space* telescope was orbiting around Pluto instead of the Earth? (There is no gas between the planets.)

3.6 Nova: Finding Life Beyond Earth

The first episode of the series begins with an exploration of Titan. After Titan we'll skip to the next episode "Moons and Beyond" which will cover Io, Europa, Enceladus, and back to Titan.

1. How large is Titan?
2. Why had we not been able to see its surface before Cassini?
3. What did the Huygens probe do?
4. What did it find about Titan's surface features?
5. What did the ground of Titan look like but what did the other sensors tell us about the ground?
6. How did Cassini view Titan's surface from high above?
7. What did Cassini find scattered over the surface?
8. What is the liquid on Titan's surface made of?
9. What are the rocks and mountains on Titan made of?
10. What is the form of precipitation on Titan and what is its composition?
11. What are the implications of finding liquid on Titan?
12. What would finding life on Titan mean for the possibility of life elsewhere in the galaxy?

    The episode continues with exploration of Mercury, Venus, asteroids, comets and Mars. We will skip to the next episode *"Moons and Beyond"*.

13. What three key things are needed for life?
14. What are organics made of?
15. Why is a liquid medium needed?
16. Why did we think that places beyond Mars could not have life?
17. What unexpected thing did Voyager find on Io when it flew by Io in the late 1970s?
18. Why were these things not expected to be found on Io?
19. Where does Io's internal energy come from?

20. What were the astrobiology implications from the discovery of volcanoes on Io?

21. Why can life not exist on Io?

22. How big is Europa and what is its surface covered with and how cold is the surface?

23. What two things did the Galileo craft find on Europa's surface?

24. Where on Earth do we find similar features?

25. What do the magnetic field measurements on Europa indicate?

26. How much liquid water could Europa have?

27. What could keep water liquid on Europa?

28. Where on Earth would conditions be like what we find below the surface of Europa?

29. What do we find at the Earth's ocean floor and what compounds are being spewed out?

30. What do find near the vents on the ocean floor?

31. How do microbes generate energy so far from the sunlight on the ocean floor?

32. What do the discoveries of the Earth's ocean floor mean for the prospects of life on Europa?

33. What three obstacles are there in searching for life on Europa?
    (a)
    (b)
    (c)

34. How big is Enceladus?

35. What unique features are found on Enceladus's icy surface that are not found on the other icy moons of Saturn?

36. What features does Cassini find at Enceladus's south pole and how big are they?

37. What did Cassini's thermal imager find at Enceladus's south pole?

38. What did Cassini find when it was behind Enceladus and looked back toward the Sun?

39. From where are these things coming from and how high up do the features reach?

40. What supplies Enceladus's internal energy to produce the geological activity?

41. What did Cassini find when it flew through the jets of Enceladus?

42. What might we find if we could scoop up the snow on Enceladus?

43. In what four extreme places on Earth has life been found?
    (a)
    (b)
    (c)
    (d)

44. What does the research on extremophiles tell us about the possibility of life elsewhere?

45. What large moon of Saturn could have life of very different chemistry than terrestrial life?

46. What did Cassini's radar find on Titan's surface?

47. What special feature does Titan share only with the Earth?

48. Why is a liquid medium needed for life? What three things does the liquid enable?

49. In order for life to exist on Titan, what fundamental process must be present?

50. How do we reproduce the conditions of Titan in labs on the Earth?

51. (a) What first basic question did Chris McKay want to answer by reproducing puddles of liquid methane?
    (b) What second basic question did he want to answer?

52. How does the search for life in our solar system inform us about our search for life in other star systems?

Every 10 / = 0.5; every 10 O = 1;
10 / ⇒ 4.5, 20 / ⇒ 4, 30 / ⇒ 3.5, etc.

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3.7 Dawn Mission Video worksheet

(3 pts)

1. What was happening often in the early solar system?

2. What asteroid is responsible for many of the bright, long meteors?

3. What is the reason for the Dawn mission?

4. What are Vesta and Ceres like and why are they the object of study?

5. How many other teams of people besides JPL are involved with the Dawn mission?

6. What will be used to provide power to the spacecraft?

7. What is different about Dawns propulsion system than the usual rocket engine?

8. Since its thrust is so tiny, how can it get to such high speeds?

9. How long will it take to reach its first target, Vesta? Dawn launched in Sept 2007, so when is it expected to reach Vesta?

10. What is so important or fascinating about the asteroid belt?

11. What is Vesta like on the surface and in its interior? In what ways is it like the Earth?

12. What will the visible/infrared spectrometer and the gamma ray neutron spectrometer tell us?

13. What information does the framing cameras give us?

14. What will the gravity science (measuring minute changes in Dawns orbit) give us?

15. How long a time will it take Dawn to travel to Ceres and how far a distance will it travel?

16. What is Ceres like and how is it a dwarf planet?

17. Why did Ceres not get any bigger?

18. What is believed to lie below Ceres surface?

19. What are some other reasons for understanding the asteroids that are given at the end of the video?

Every 6 / = 0.5; every 6 O = 1;
6 / $\Rightarrow$ 2.5, 12 / $\Rightarrow$ 2, 18 / $\Rightarrow$ 1.5, etc.

3.8 Radioactive Dating Worksheet

half-life—the time required for one-half of a radioactive material to decay to a more stable material (it is NOT one-half the age of the rock!).

Follow the Basic Steps from the lecture outline (or in the textbook) to answer the following questions.

1. If the **half-life** of a radioactive rock is 1 month, is the rock completely decayed after 2 months? If not, why not and how much is left?

2. The radioactive material Uranium-235 has a **half-life** of 700 million years. How long will you have to wait until a 1-kilogram chunk decays so only 1/16 kilogram is left?

   (a) How many half-lives will it be until only 1/16th is left?

   (b) How many years will that be?

3. (a) A rock in Bishop, CA has 1/8 of the original amount of Uranium-238 left from when it first solidified long ago. Therefore, it is _____________ half-lives old. If the **half-life** of Uranium-238 is 4.5 billion years, the rock is _____×_____________ years old = _____________ years old.

   (b) How long ago did the planets and the Sun form? (Hint: see the definition of **primitive** in section 10.1 and 10.2 of the textbook.)

   (c) Choose one from among the following for the *original* source of the rock from Bishop: geologic fault, Earth's interior, Moon's surface, outside the solar system, Jonathan Frake's private collection.

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3.9 Stardust Mission Video Worksheet

(5 pts for both)

1. What are comets like (including their composition)?
2. Why are they important?
3. What is the comet nucleus like when it is far from the Sun?
4. Within what planets orbit does a comet form its coma (atmosphere)?
5. Which comet was the destination for Stardust? (Note the video shows an accurate representation of what the nucleus looks like.)
6. What was the "first" that Stardust accomplished?
7. How long a time and how far a distance did Stardust take to reach the comet?
8. How did Stardust collect comet particles?
9. What special material was used and why was it used?
10. How fast was Stardust traveling with respect to the comets nucleus and how close did it get?
11. How long a time did it take after the encounter for its cargo to return to Earth?
12. Where on Earth did the capsule land and how fast was it going through the air?

(The capsule landed safely and the comet particle samples have been analyzed. They do contain some stardust grains from other stars but the majority of solids are solar system materials that appear to have formed over a very broad range of solar distances and perhaps over an extended time range.)

Over for Deep Impact worksheet

3.10 Deep Impact Mission Video Worksheet

1. Why are comets important?
2. What was the comet expected to be like?
3. What was the "first" that Deep Impact accomplished?
4. How fast was the spacecraft traveling with respect to the comet?
5. What was unexpected about Tempel 1 nucleus surface?
6. What is the comet nucleus material like? (Strength of material, how porous, density)
7. What two unexpected things did Deep Impact find out about comets?
8. What minerals are in the comet dust and where would they have formed?
9. What materials did the Spitzer infrared space telescope find and where would they have formed in the early solar nebula?
10. Where would the ices have formed?
11. What other unexpected thing was discovered about this comet? How is this similar to what the Stardust mission found?

Every 4 / = 0.5; every 4 O = 1;
4 / $\Rightarrow$ 4.5, 8 / $\Rightarrow$ 4, 12 / $\Rightarrow$ 3.5, etc.

3.11 Origins: The Birth of Earth

At the beginning of the video Neil deGrasse Tyson compresses the entire history of the Earth down into one 24-hour day (reminiscent of the "Cosmic Calendar" in chapter 1 of the textbook). The present (today) is at midnight at the end of the compressed day and the Earth's birth is at the previous midnight 24 hours ago on the compressed day.

1. How long a time in "real time" does 24 hours represent on this compressed clock? (Remember this number!) _____________
   (a) When humans appeared _____________
   (b) When dinosaurs appeared _____________
   (c) When the first multi-celled animals appeared _____________
   (d) When the first single-cell animals appeared _____________
2. Where did the elements (atoms) heavier than helium like Carbon, Iron, Gold, Uranium, etc., come from?
3. From what did the solar system form and where was the Sun?
4. What happened to all of the Hydrogen and Helium?
5. Where were the dust grains made of heavier elements located?
6. What happened to the dust grains as they orbited the Sun?
7. When large rocks had been created, how were they able to grow into much larger pieces (called "planetesimals")?
8. Why is there no material (rocks, etc.) left from the time of Earth's birth?
9. What gives us clues of the Earth's infancy?
10. What is a **carbonaceous chondrite**?
11. Why are meteorites important?
12. How do we get the ages of the meteorites?
13. (a) How do we find out when the planets started forming?
    (b) How do we find out how quickly they formed?
14. a) Describe the "Iron Catastrophe".
    b) When did it happen in real time and in the compressed clock?
15. What happened to the heavy elements like iron + nickel and what happened to the lighter elements?

16. Why do we need a magnetic field? (What would happen if we did not have a magnetic field?)

17. Why does not Mars have a magnetic field?

18. What was our atmosphere like long ago?

19. Besides the Moon rocks being younger than the Earth, what two things were surprising about the composition of the Moon rocks?

20. a) How was the Moon created?
    b) When did it happen in real time and in the compressed clock?

21. (a) How much closer was the Moon than today?
    (b) If Moon is 240,000 miles away now, how far away was it from Earth when it formed?

22. a) How many hours long was an Earth day long ago?
    b) Why is the Earth day longer today? (Why is it spinning slower today than long ago?) Note that the Moon moving away is an *effect* not a cause!

23. Why is it so hard to determine when the Earth's surface cooled enough to solidify? (Why doesn't any of the original crust survive today?)

24. a) What are zircons?
    b) Why are zircons important?

25. When did the Earth's crust form?

26. What had to happen before liquid water could form?

27. When did liquid water first exists on the Earth?

28. What are two possible sources of the liquid water on Earth?

29. What are comets made of and how big are they?

30. How can the theory that says Earth's oceans came from comet impacts long ago be tested?

31. How is the water content measured in a comet?

32. a) What must a scientist not do with his/her theory? b) When must a theory be given up?

33. What was the next crucial phase in the Earth's development?

Every 6 / = 0.5; every 6 O = 1;
6 / ⇒ 4.5, 12 / ⇒ 4, 18 / ⇒ 3.5, etc.

3.12 Nova: Alien Planets Revealed

The number of exoplanets is now over 1700 and Kepler mission will be adding a few thousand more to our catalog. How do we find exoplanets? Some of them are habitable. What would life look like on those exoplanets?

1. What is the two-part mission of the Kepler spacecraft mission?
2. In what wavelength band (part of the EM spectrum) does Kepler observe?
3. What type of star is Kepler 16?
4. What is so unusual about the exoplanet Kepler 10b?
5. How hot is Kepler 10b?
6. What is the primary mission of the Kepler mission?
7. How can we figure out what life might be like on other worlds?
8. How is Kepler different than other space telescopes (including Hubble)?
9. Where in the sky did Kepler fix its attention and how many stars were in that patch of sky?
10. How does Kepler find exoplanets if they are too small and dim to image directly?
11. How much dimmer is an exoplanet typically than its host star?
12. How does Kepler measure the size of an exoplanet?
13. How many exoplanet candidates had Kepler found in its first 15 months of operation and what was the range in sizes of the exoplanets that Kepler had found (largest and smallest sizes)?
14. What type of exoplanets can exist?
15. When were hydrogen and helium made and what made the elements heavier than helium?
16. What elements are essential to life?
17. What do we follow (look for) in order to find life?
18. What was the self-limitation imposed by the Kepler team?
19. What is the key feature of Earth that makes it possible for life to exist on the Earth?

20. Have we found any life forms that can live without this special ingredient?

21. What extreme dry places on Earth have been searched for life forms that don't use water? (Name at least two.)

22. Where has water been found beyond the Earth?

23. What is the "Goldilocks zone" (aka "habitable zone")?

24. What is the core mission of Kepler?

25. How do we use the timing of each transit to figure out the distance of the exoplanet from its star?

26. How do we use the distance of the exoplanet from its star to get its surface temperature?

27. What is the orbital period (time) of Kepler 22b and how many times does an exoplanet have to transit its star for us to be sure that the transits are periodic-repeatable?

28. What is the special distinction of Kepler 22b and how far away is it?

29. What do all planets/exoplanets start out with?

30. How can some exoplanets get really large?

31. How big is Kepler 22b? Between what two planets sizes in our solar system would Kepler 22b be placed?

    This next section of the show describes how we can find out what an exoplanet like Kepler 22b is made of

32. What is another way of detecting exoplanets?

33. How do we use the amount of the star wobble to get the planet's mass?

34. How do we use an exoplanet's size and mass to find out what it is made of?

    Note that when Sara Seager says that a planet over seven times the mass of the Earth can have water, that seven Earth-mass is actually the *upper limit* for a habitable world.

35. How much water could Kepler 22b have? How deep would its water ocean be?

36. What are the necessary ingredients for life?

37. What is an essential property of a molecule for life?

38. What is one definition of life used in the episode?

39. What must the molecules of life contain and what must the molecules be able to do?

40. What element will be the basis of life anywhere in the Galaxy?

41. Why do we think that life beyond the Earth is likely to exist?

42. How long ago did life get started on the Earth and how long did it take before complex life evolved?

43. What is life beyond the Earth most probably like? Why?

44. What feature of the climate must be present for there to be the chance for complex life to develop?

45. What would be the main challenge of plants on a water world and how would they overcome that challenge?

46. What is special about the exoplanet orbiting KOI 2626?

47. What is problematic about the star KOI 2626? How common is that type of star?

48. Why is it easier to find a small Earth-sized world orbiting a small M-type star than one orbiting a star like our Sun?

49. What fraction of M-type stars have an Earth-sized planet orbiting them?

50. What happens to an exoplanet that orbits very near its star and why is that "bad" for habitability?

51. What did we originally think would happen to the carbon dioxide in the atmosphere on the side of an exoplanet that always faced away from the star if the exoplanet was tidally locked to its star?

52. What do computer simulations show would actually happen to the atmosphere of a tidally-locked planet?

53. How would the atmosphere circulate on a tidally-locked planet?

54. What would plants be like that live on the day-night boundary of a tidally-locked planet around a red-dwarf M-type star? What color would they be and what shape would they need to be?

55. To what are all forms of life subject?

56. What is one possible form of life on the land of a tidally-locked planet? What would it be like?

57. For an Earth-sized exoplanet orbiting a sun-like star, what is the change in brightness we must be able to detect? In the hotel example Batalha uses, how much change in position of just one of the curtains would produce that amount of change in brightness?

58. What is special about the FOURTH exoplanet discovered orbiting KOI 701 and how far away is the star from us? (The planet is now known as Kepler-62f.)

59. Assuming Kepler-62f has similar amounts of water as the Earth, what would aquatic animals be like on Kepler-62f and why?

60. What would land animals be like on Kepler-62f and why?

61. Why do all vertebrate animals on the Earth have four limbs?

62. If a vertebrate animal on Kepler-62f had eight limbs, how would it move and how can we figure that out?

63. Why do some major astrobiology researchers think that *intelligent* life is quite rare—the exception, not the rule?

64. What is the fraction of stars in the Galaxy that have an Earth-sized planet? With that fraction, how many Earth-sized exoplanets are in the Galaxy?

Every 8 / = 0.5; every 8 O = 1;
6 / ⇒ 7.5, 12 / ⇒ 7, 18 / ⇒ 6.5, etc.