Chapter 3

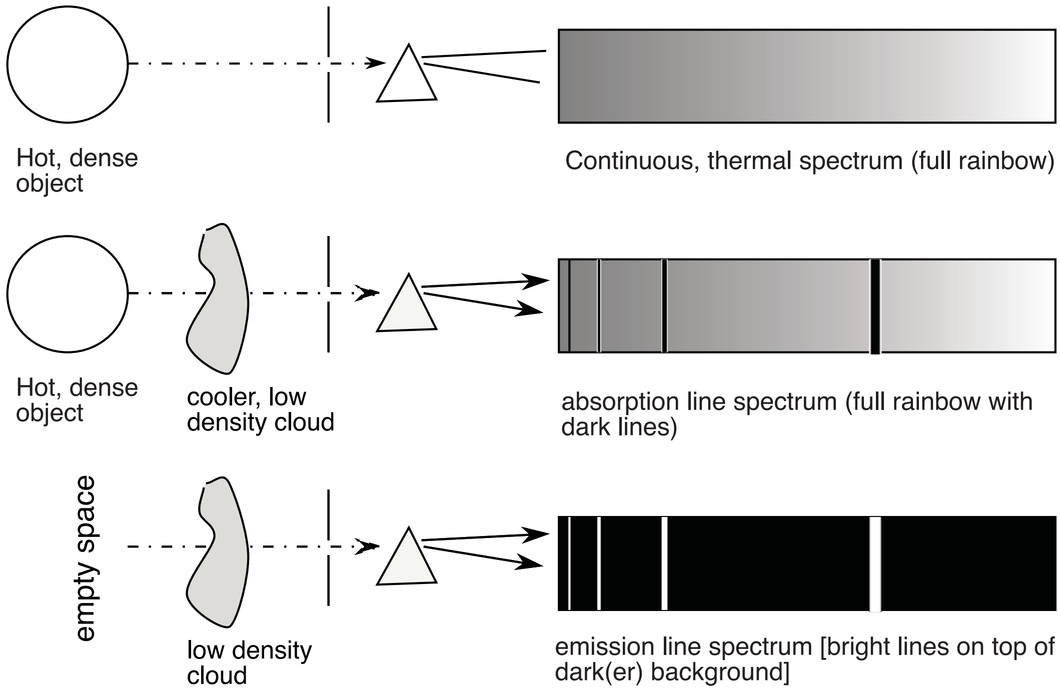
In Class Worksheets & Assignments

Worksheets and assignments begin two pages over

Worksheet next page

3.1 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.)

3.2 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.

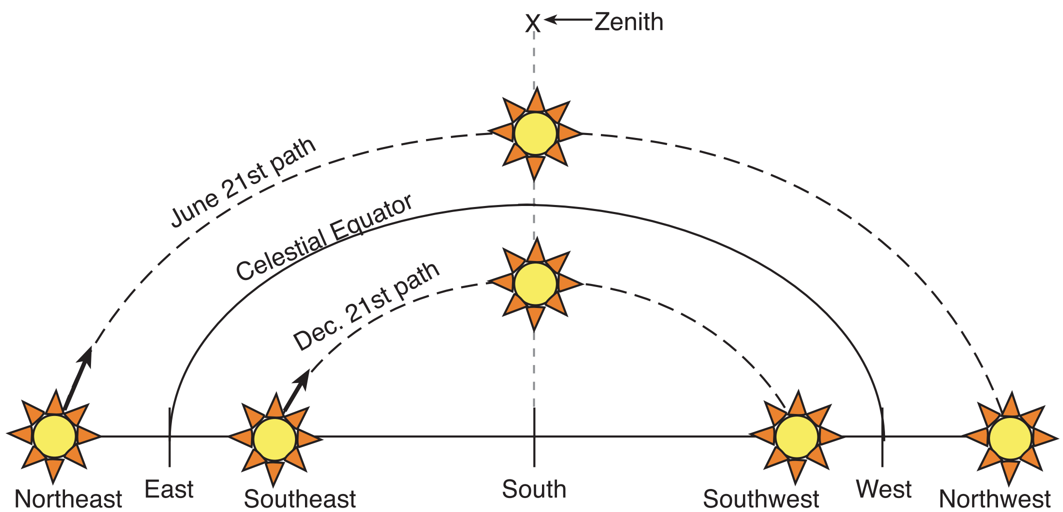


Figure 1

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?)

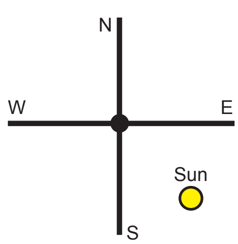
5. Does the Sun always set in precisely the same location throughout the year? If not, tell where the sun will set throughout the year.

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.



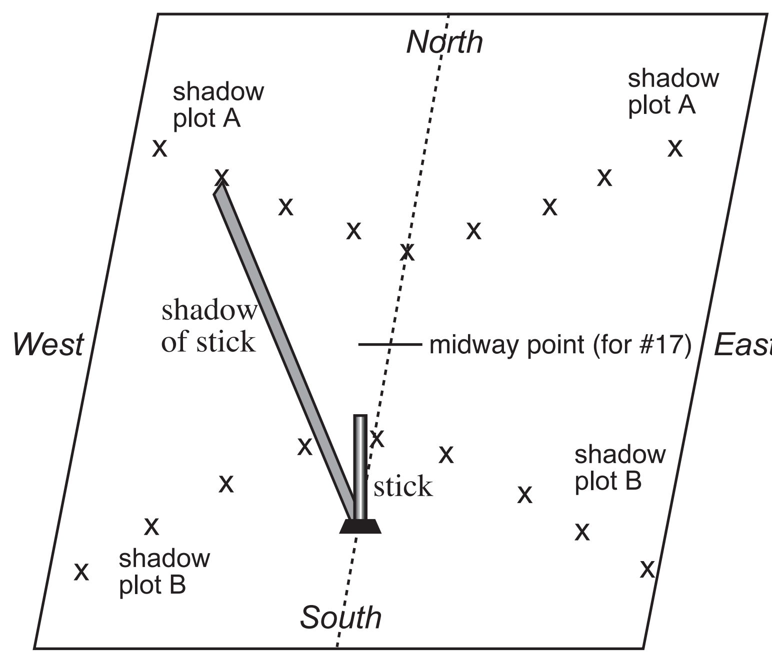


Figure 2

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.

Lunar Phases Worksheet 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.

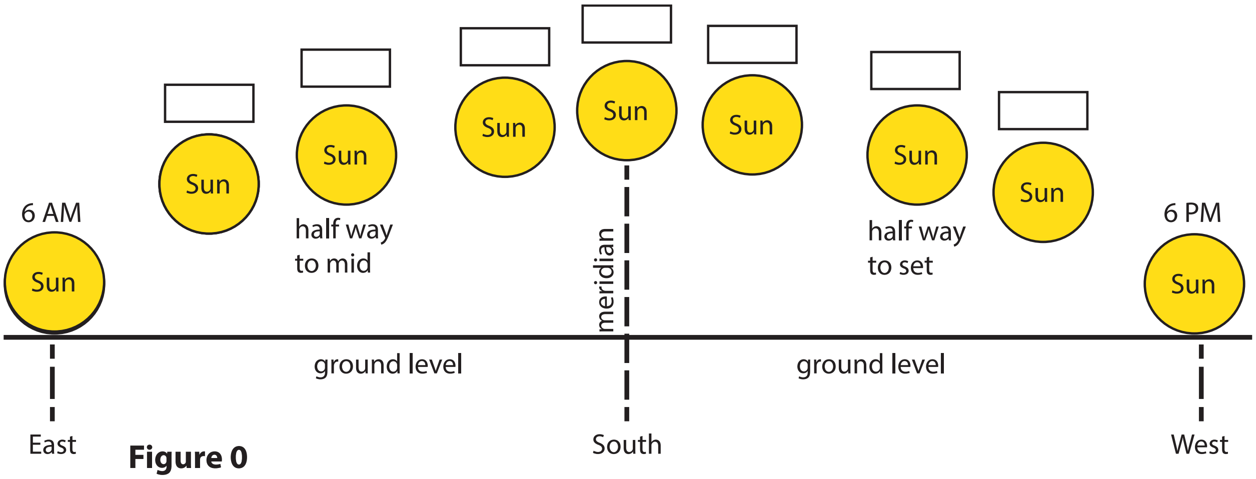


Figure 0

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.

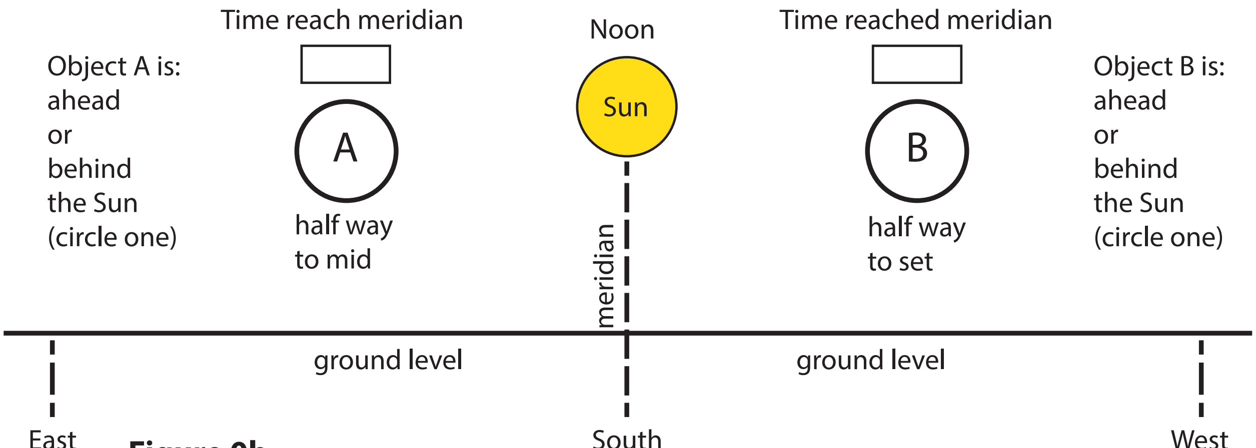


Figure 0b

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.

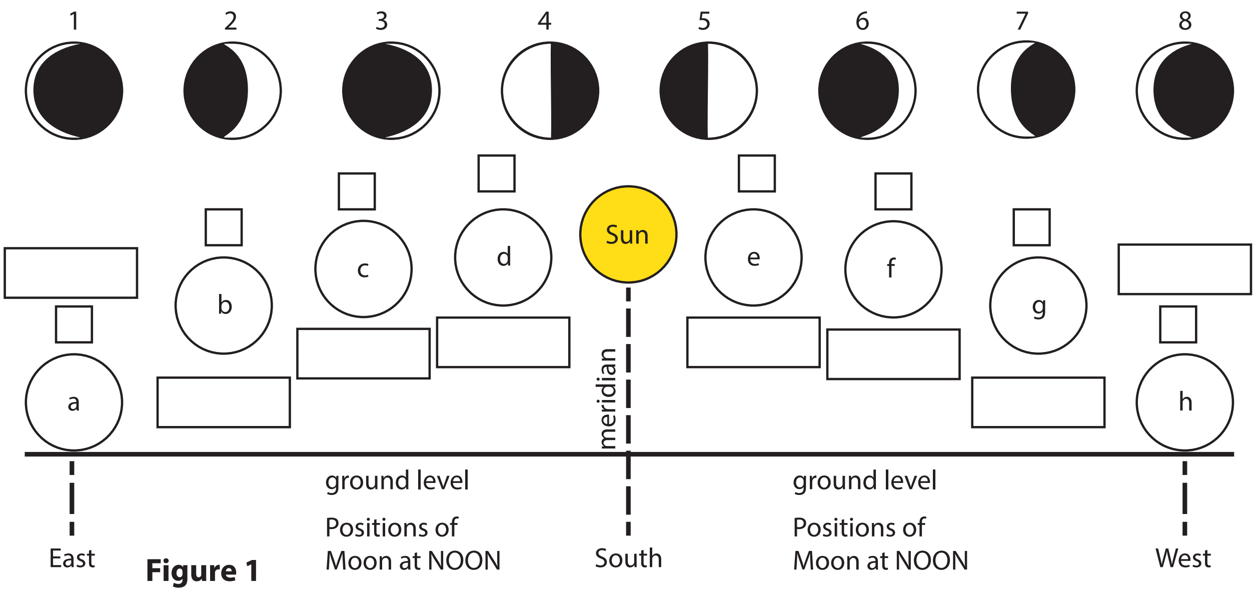


Figure 1

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: ______________________

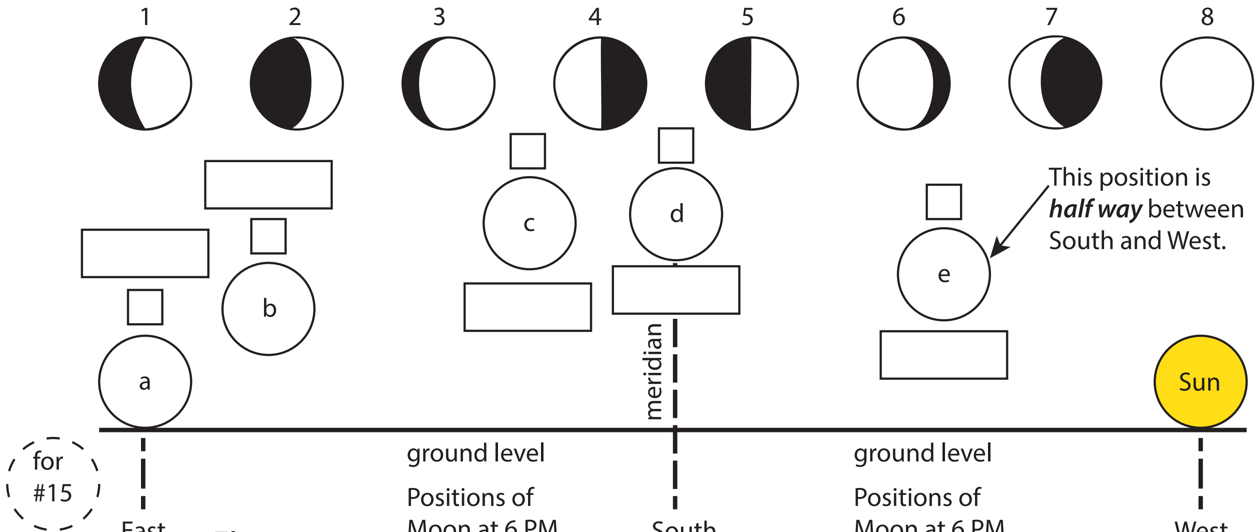


Figure 2

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".)

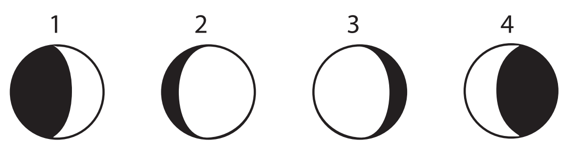


Figure 3

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).

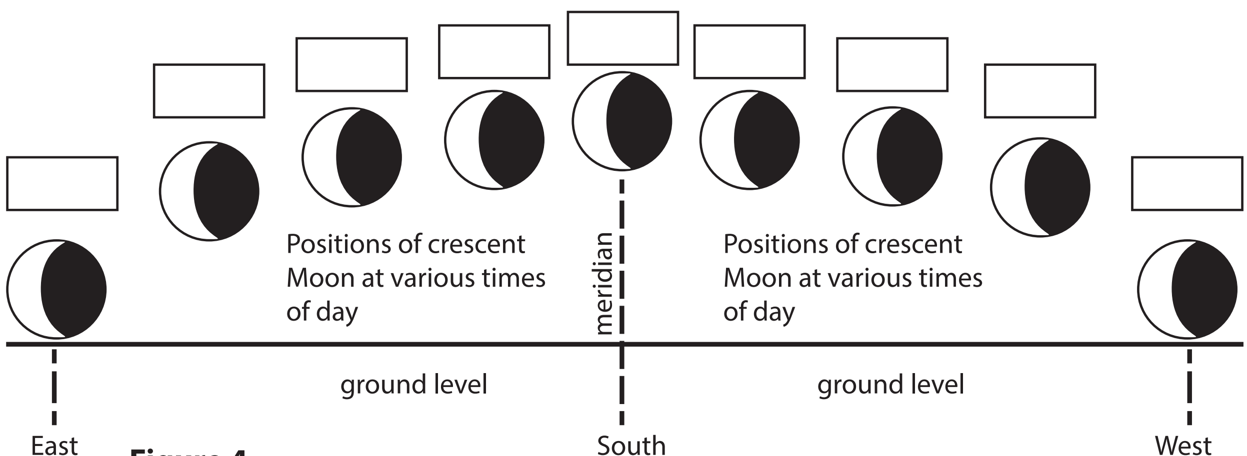


Figure 4

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).

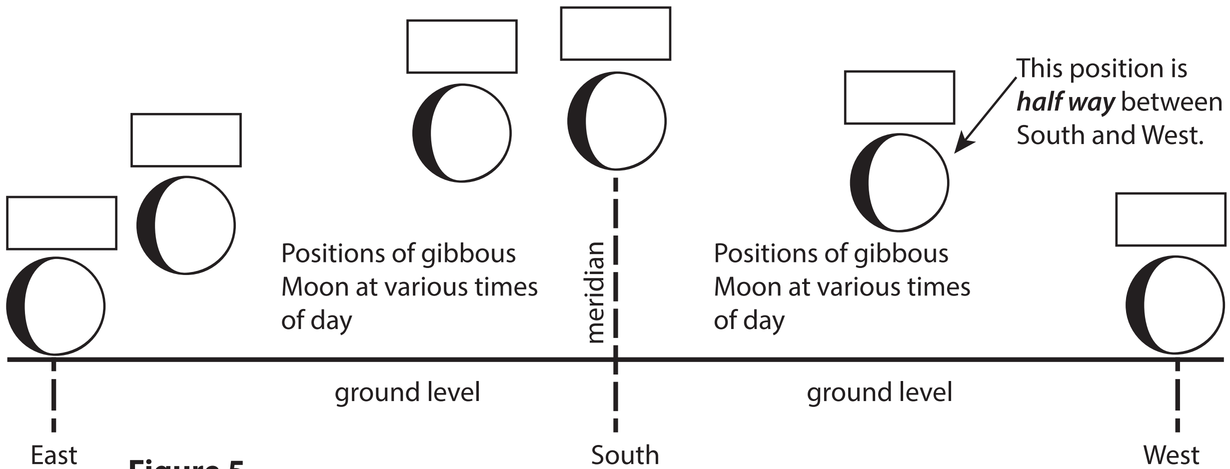
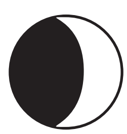


Figure 5

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)?

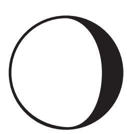
14. The phase picture below shows the waxing crescent phase for position (e) of Figure 2. *Using the pattern of rising & setting motions* of the Moon from the waning crescent and waxing gibbous examples, give the appropriate *time of day* for the given positions.



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 _______________

 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.

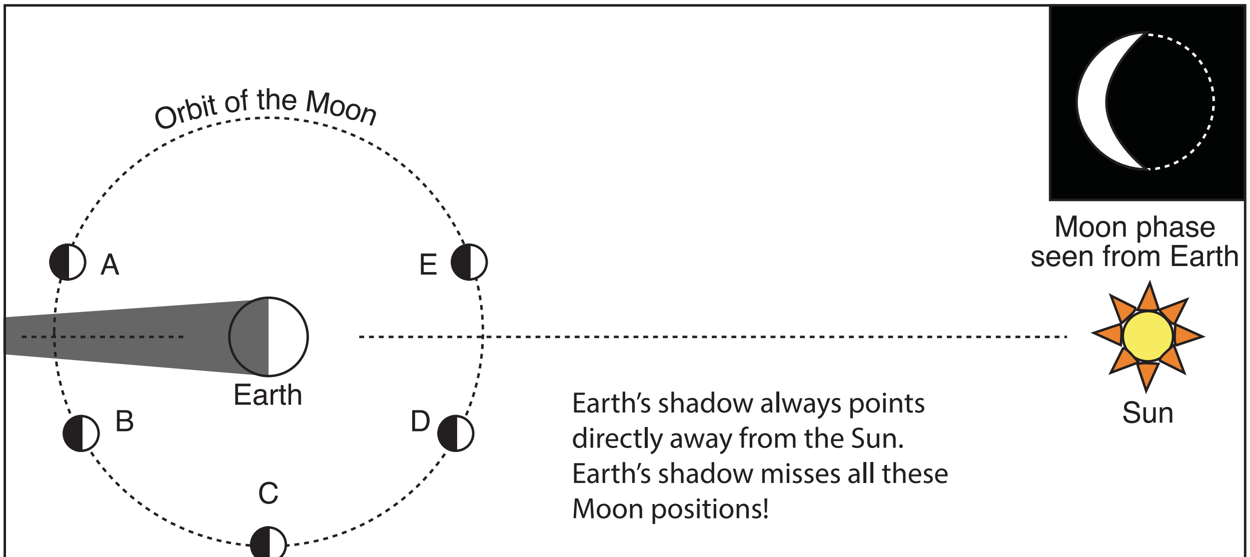
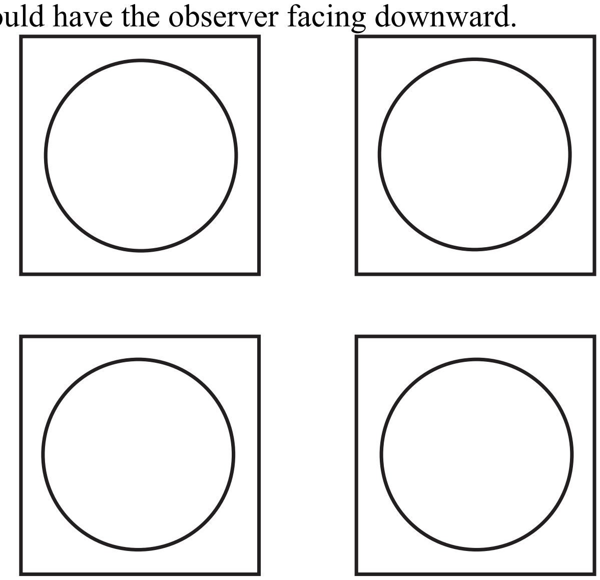


Figure 6

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 <u>*not*</u> 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.

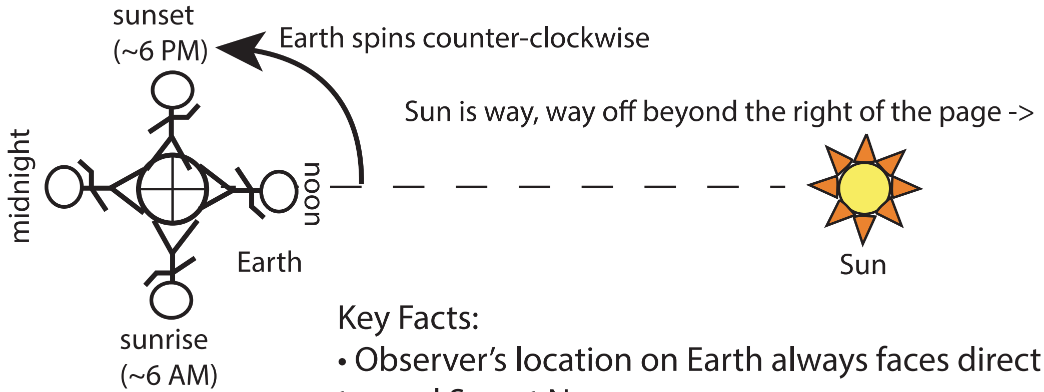
Shade in the part that is dark as seen from the Earth (what we do not see lit).



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!

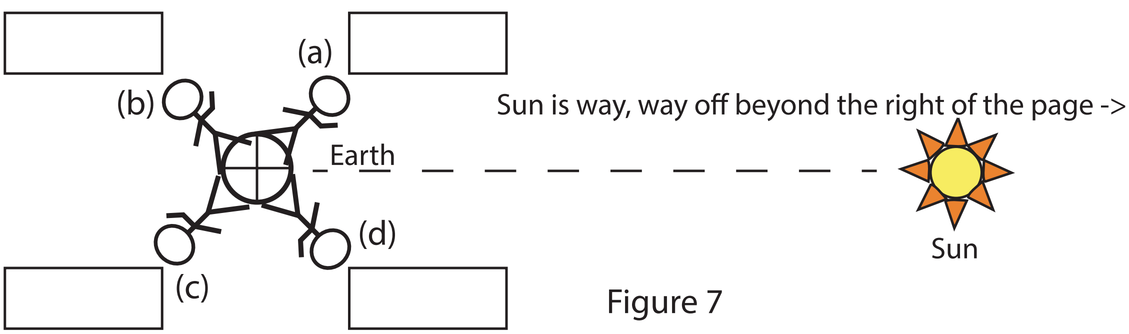


Figure 7

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).

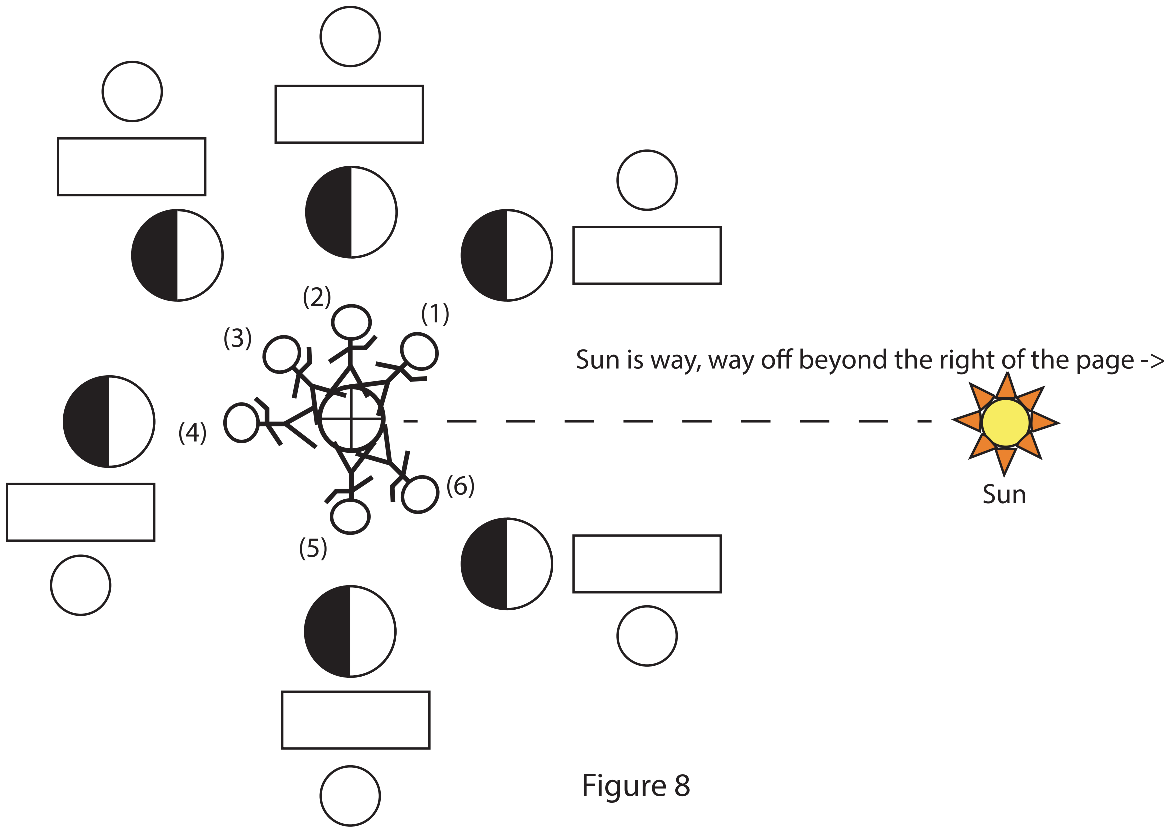
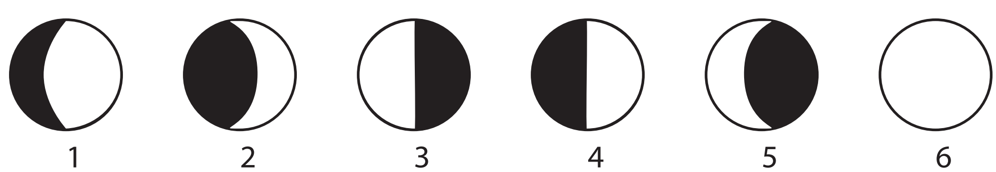


Figure 8

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.



3.3 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

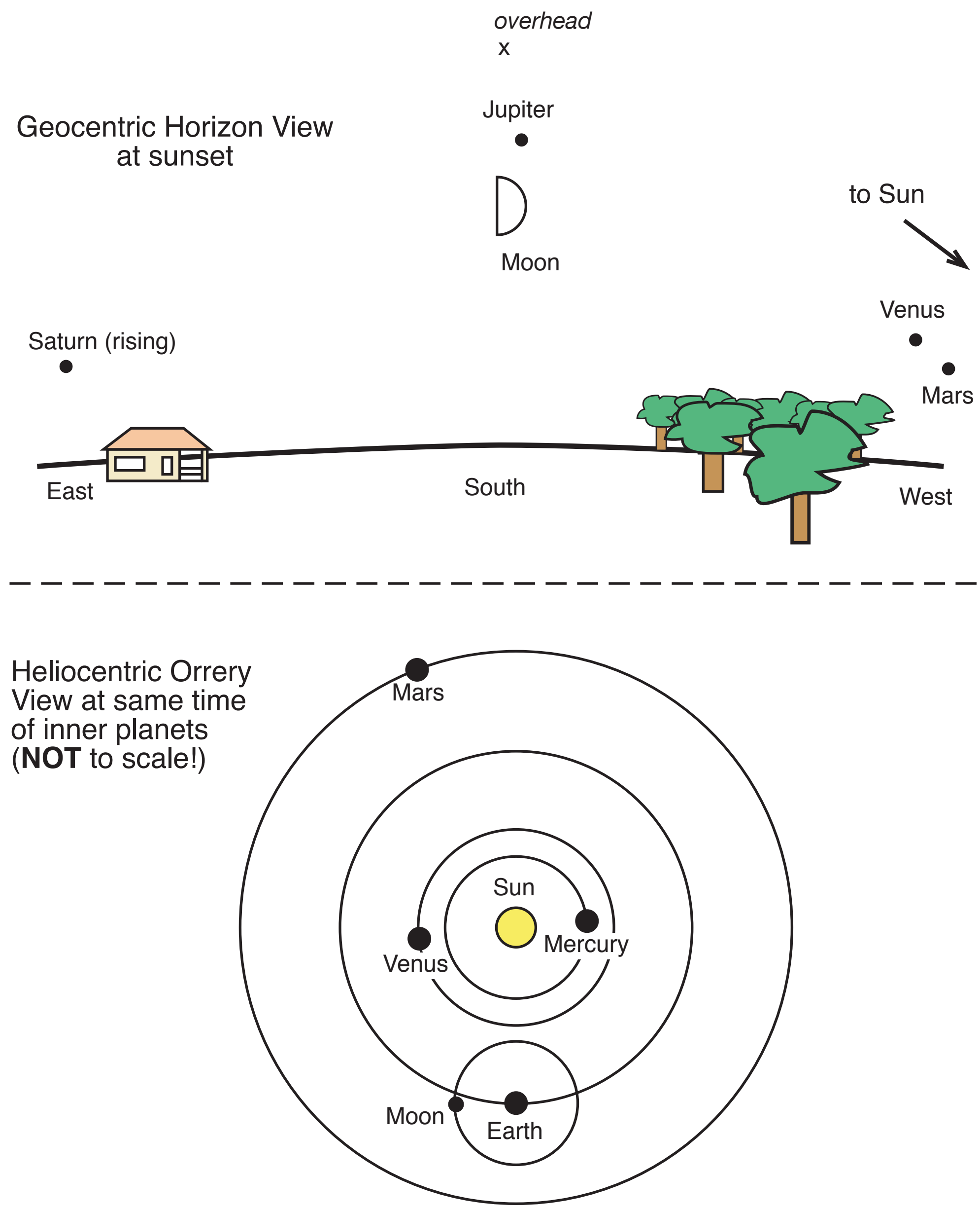
Skeptic: ____

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 **heliocentric** 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.

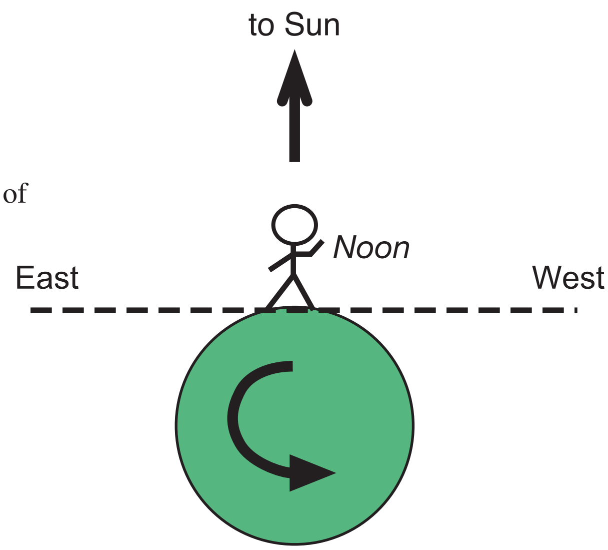


Part I: Rising and Setting Times

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:

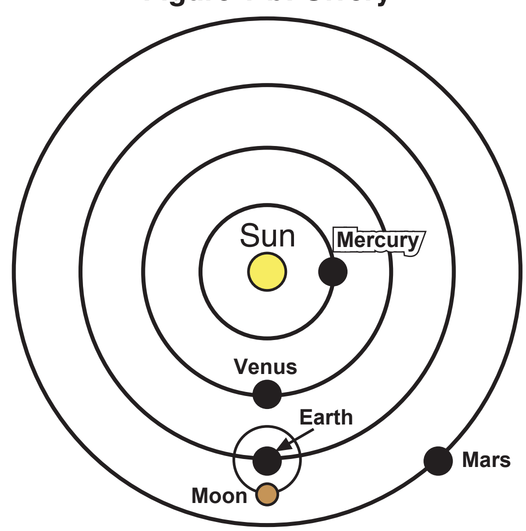
Venus: ______________________________

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.

Meridian goes through exact south and zenith.

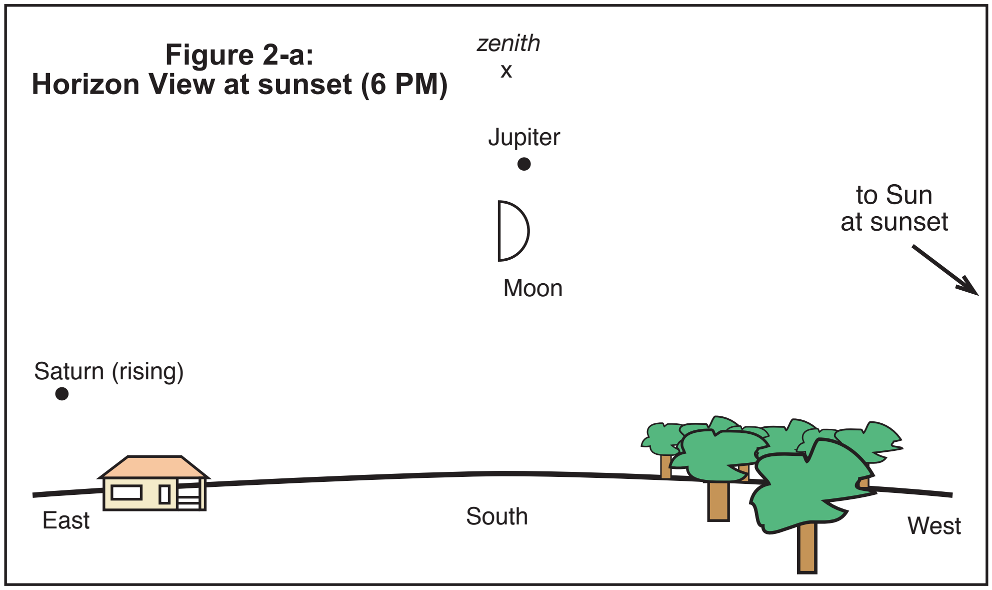


Figure 2-a:
Horizon View at sunset (6 PM)

Sky Object	Rise Time	Set Time
Sun		
Jupiter		
Moon		
Saturn		

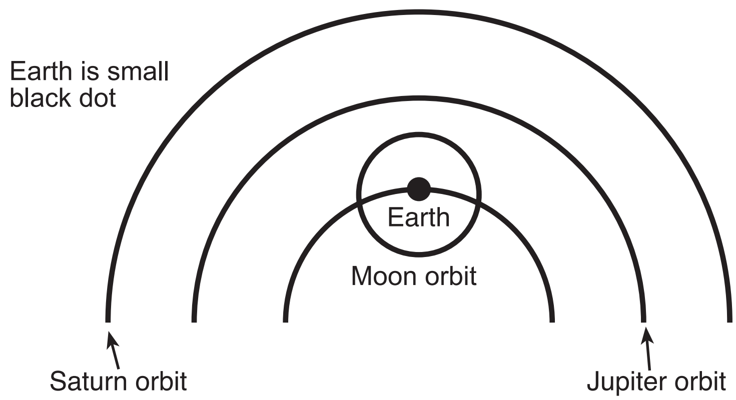


Figure 2-b:
Orrery NOT drawn to scale!

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

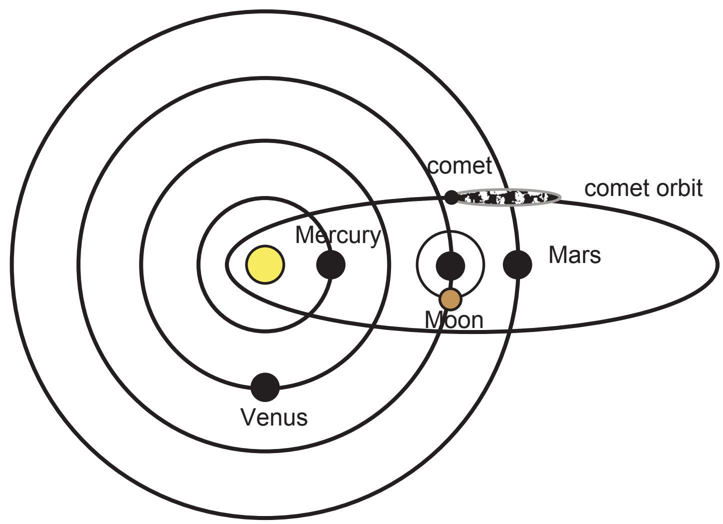
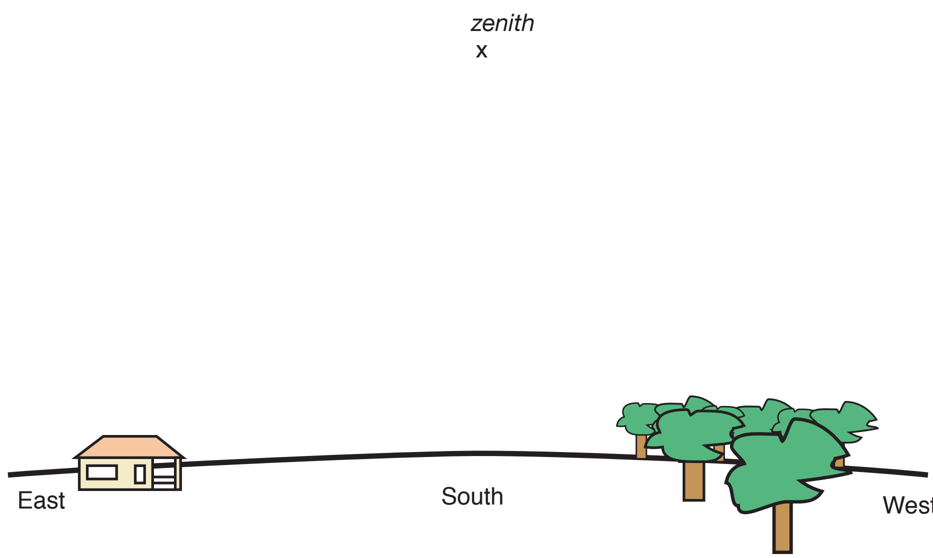


Figure 3-b: Geocentric Horizon View at Midnight

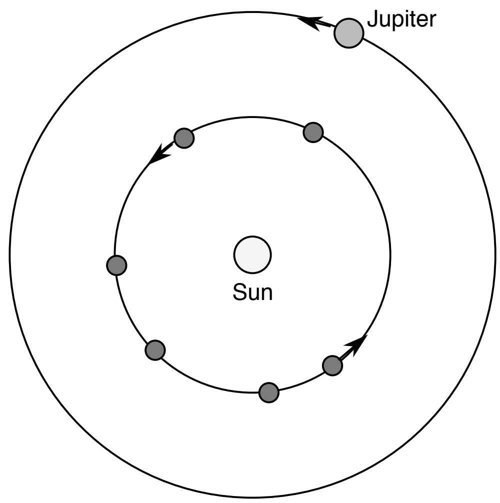


Draw the positions of the objects in the sky as we would see them from on the ground, i.e., translate Figure 3-a to Figure 3-b. If an object is below the ground at midnight, be sure to explicitly say so or draw it and label it below the ground.

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?

3.4 History of Astronomy

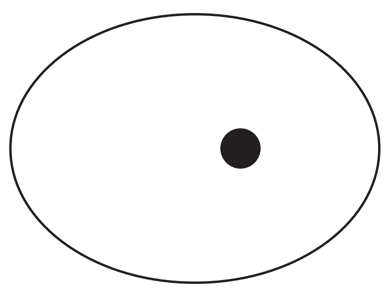
1. (0.5 pt) Circle the position of the Earth that will make Jupiter appear to move in a retrograde loop: (hint: see retrograde motion definition or concept 3 on exam#2 review sheet)



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

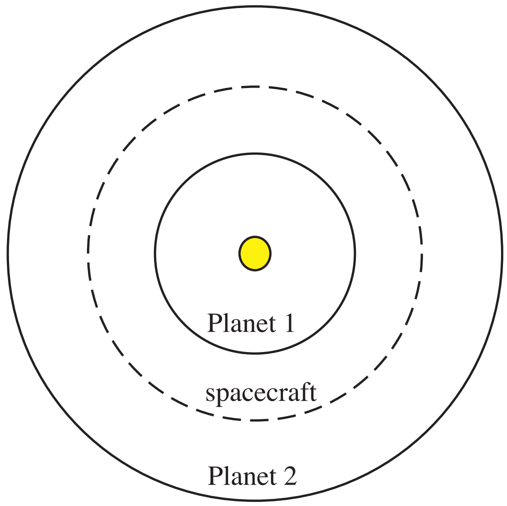
   (a) What is the *semi-major axis* of its elliptical orbit?

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



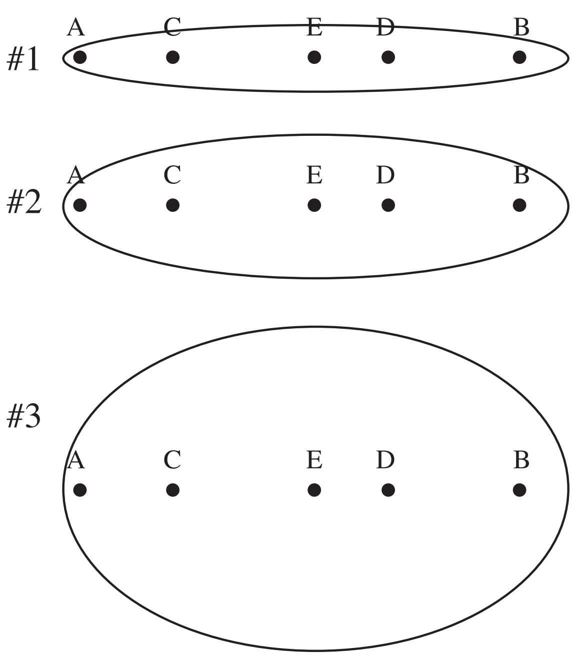
O V E R

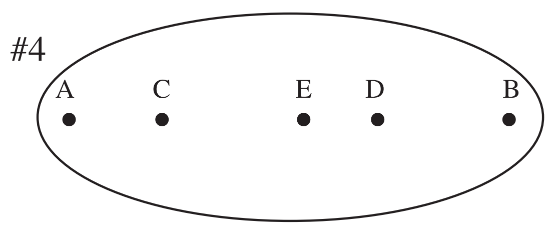
3. (1 pt) NASA wishes to put a satellite into a circular orbit around the Sun with an orbital period of 16 years.



   (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 ______

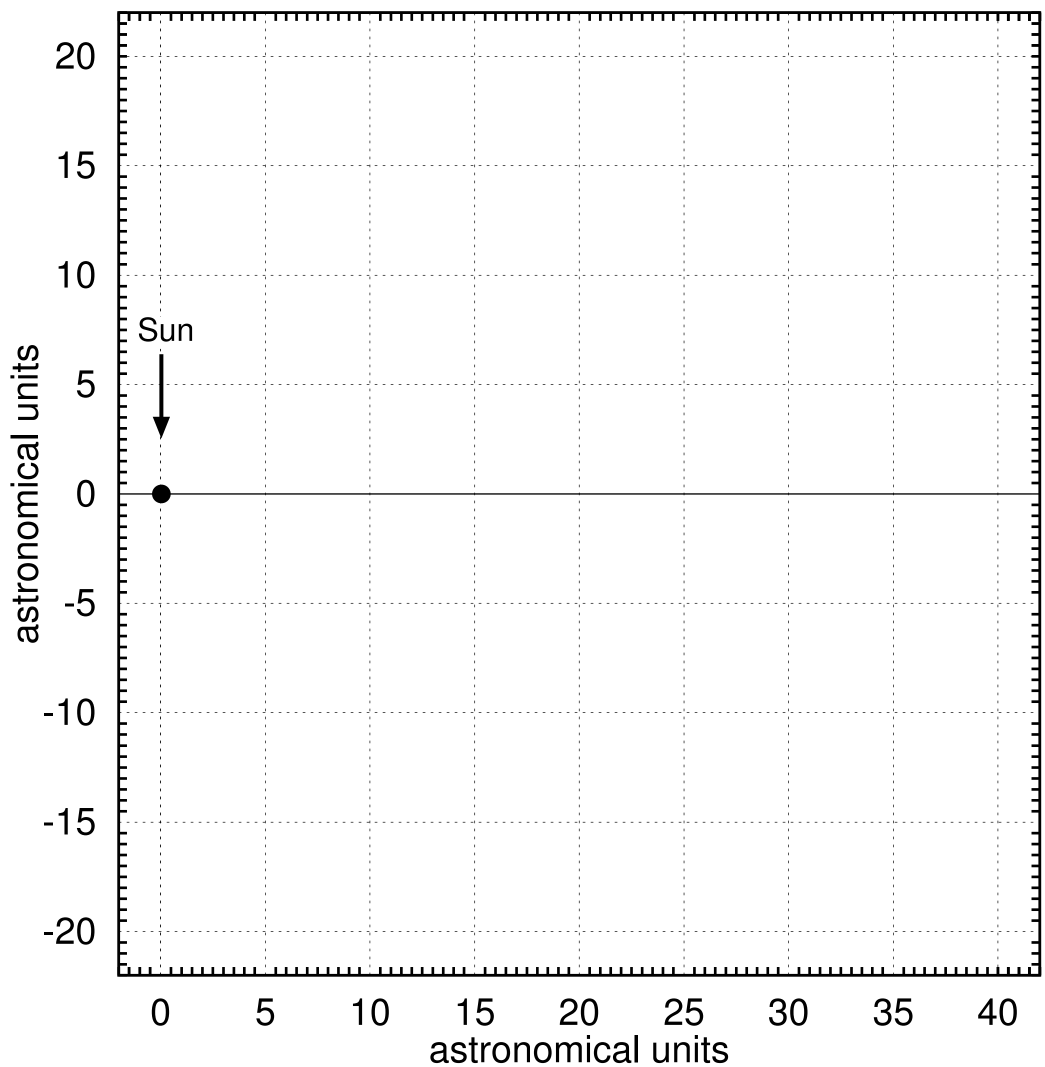
N E X T P A G E

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** (**Note:** this is less than 1 of the tiny 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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3.5 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.

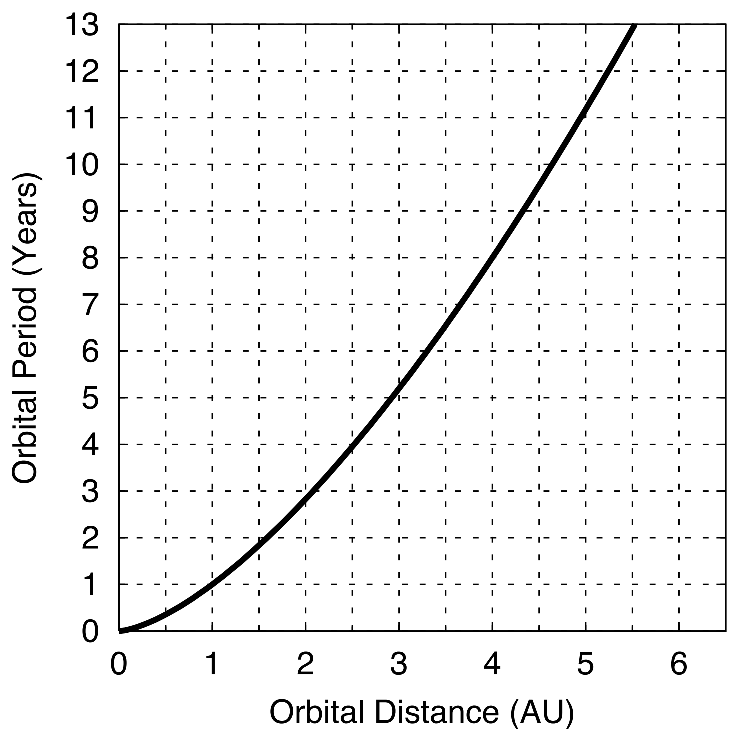
1. Which of the two planets (Moto or Spec) do you think will move around the central star in the least amount of time? Why? *It might help to draw a picture of the planets and orbits.*

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$\Rightarrow$ 2.75, 2 O = 10 C $\Rightarrow$ 2.5, 3 O = 9 C $\Rightarrow$ 2.25, etc.

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3.6 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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3.7 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.

3.8 Parallax and Distance tutorial

Courtesy of Adams, Prather, Slater and CAPER Team

Part 1: Angular Measurement

Imagine that you are standing in an open field. While facing south, you see a house *far away* in the distance. If you look to the east, you see a barn *far away* in the distance.

1. What is the angle between the house and the barn? (Hint: If you point at the barn with one arm and point at the house with your other arm, what angle do your arms make?)

2. You see the Moon on the horizon just above the barn in the east, and also see a bright star directly overhead. What is the angle between the Moon and the overhead star?

3. Compare your answer for the barn-house angle from question 1 and the Moon-star angle from question 2. Are they the same? Does this separation angle tell you anything about the actual distance (# miles) between the barn and house or the actual distance (# miles) between the Moon and star?

We are unable to *directly* measure distances to objects in our night sky. However, we can obtain the distance to relatively nearby stars by using their parallax angles (see section 11.1 in your textbook). Because even these stars are very far away (up to about 500 parsecs), the parallax angles for these stars are very small. They are measured in units of *arc seconds*, where 1 arc second is 1/3600 of one degree. To give you a sense of how small this angle is, the thin edge of a credit card, when viewed from one football field away, covers an angle of about 1 arc second.

Part 2: Finding Stellar Distance Using Parallax

Consider the star field drawing shown in Figure 1. This represents a tiny patch of our night sky. In this drawing the angle separating the two bright stars Stars A and B is just $\frac{1}{2}$ of an arc second.

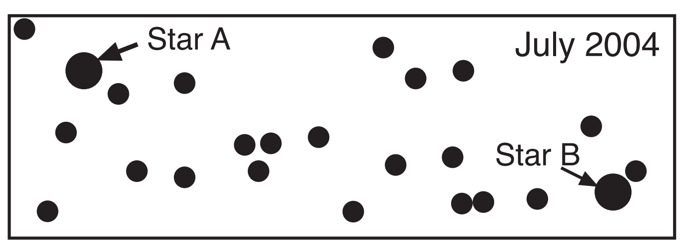

Figure 1

In Figure 2 (see the last page of this activity) there are pictures of this star field taken at different times during the year. One star in the field exhibits parallax as it moves back and forth across the star field with respect to the other, more distant stars.

4. Using Figure 2, determine which star exhibits parallax. Circle that star on each picture in Figure 2. (Hint: compare two fields seven months apart, such as May and October, back and forth rapidly.)

5. In Figure 1, draw a line that show the range of motion for the star exhibiting parallax in the pictures from Figure 2. Label the endpoints of this line with the months when the star appears at those endpoints.

6. How many times bigger is the separation between Stars A and B compared to the distance between the endpoints of the line showing the range of the motion for the star exhibiting parallax?

7. Recall that Stars A and B have an angular separation of $\frac{1}{2}$ of an arc second in Figure 1. Consider two more stars (C and D) that are separated *twice* ($2\times$) as much as Stars A and B. What is the angular separation between Stars C and D in arc seconds?

8. What is the angular separation between the endpoints that you marked in Figure 1 for the nearby star exhibiting parallax?

Note: We define a star's parallax angle as *HALF* the angular separation between the endpoints of the star's angular motion.

9. What is the parallax angle for the nearby star from question 8 (what is half of question 8)?

Note: We define 1 **parsec** as the distance to an object that has a **<u>par</u>**allax angle of 1 arc **<u>sec</u>**ond. For a star with a parallax angle of 2 arc seconds, the distance to the star from Earth would be $\frac{1}{2}$ of a parsec; star parallax of 1/5 arc seconds means distance from Earth = 5 parsecs, etc.
So *from Earth* distance in parsecs = 1/ (parallax angle in arc seconds).

10. For a star with a parallax angle of $\frac{1}{2}$ of an arc second, what is its distance from us?

11. For a star with a parallax angle of $\frac{1}{4}$ of an arc second, what is its distance from us?

12. What is the distance from us to the nearby star exhibiting parallax in the pictures from Figure 2? (Hint: consider your answer to question 9.)
    (a) 1 parsec (b) 2 parsecs (c) 4 parsecs (d) 8 parsecs (e) 16 parsecs

Turn in this sheet only. Do NOT turn in the next page.

11C = 2.75, 10C = 2.5, 9C = 2.25, 8C = 2.0, 7C = 1.75, 6C = 1.5

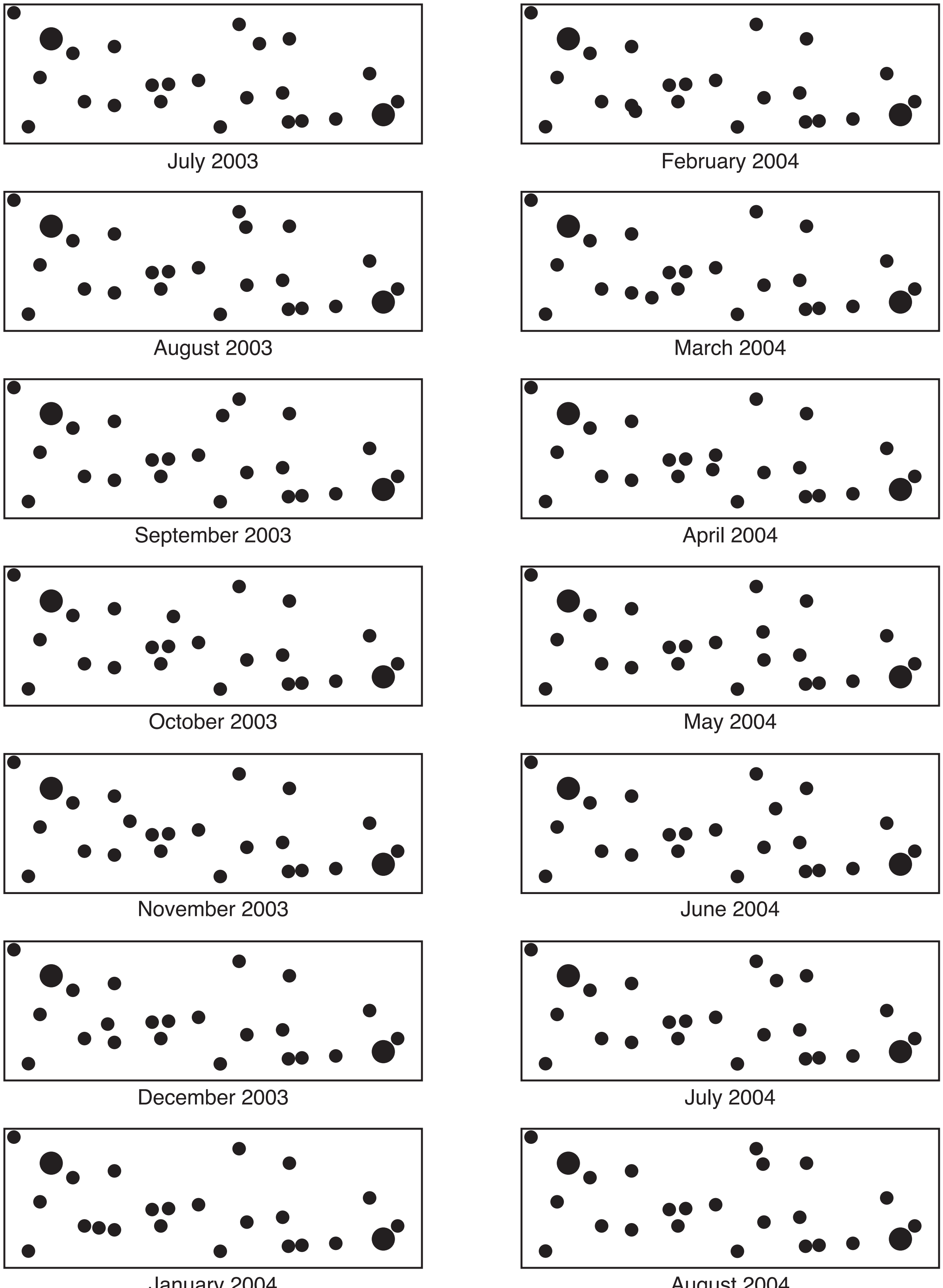

Figure 2

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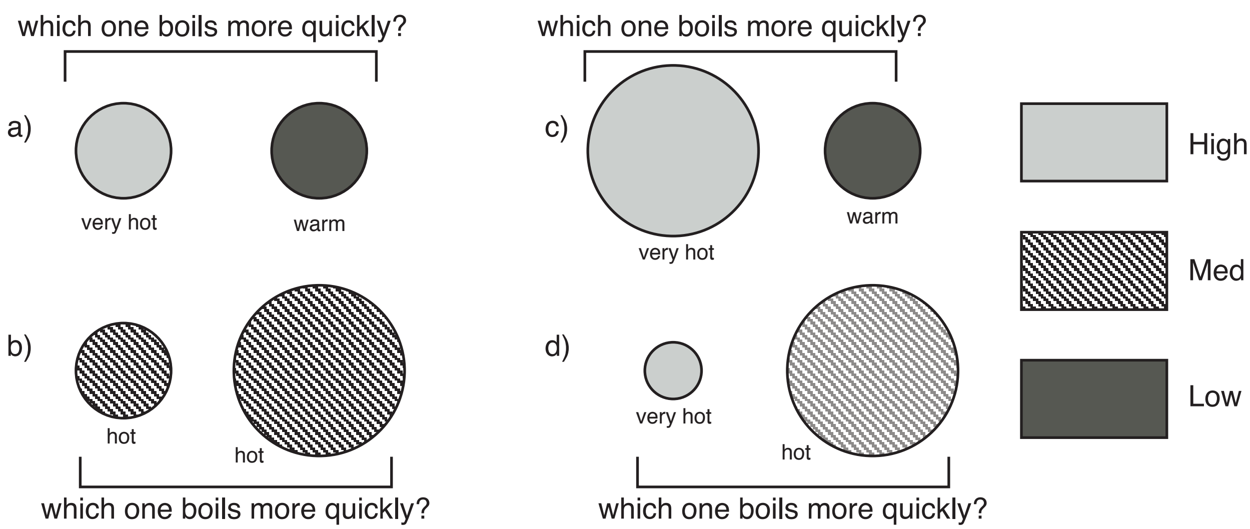
3.9 Luminosity, Temperature and Size tutorial

Courtesy of Adams, Prather, Slater and CAPER Team

Part 1: Luminosity, Temperature and Size

Imagine you are comparing the abilities of electric *hot plates* (="stove burners") of different sizes and temperatures to boil two identical large pots of 1 gallon of water. When a hot plate is at one of the temperature settings (low, med, high), the hot plate is depicted as a shade of gray pattern as shown in question 1. The lighter the shade of gray, the higher the temperature setting of the hot plate.

1. For *each* pair of hot plates (="stove burners") shown below, circle the one that will boil identical one-gallon pots of water more quickly (so which one of pair A boils the water faster, which one of pair B boils the water faster, etc.). If there is no way to tell, state that explicitly. Each one-gallon pot of water is as large as the largest hot plate and each pot is the same size and shape. The hot plate with *more power* boils the water more quickly.



2. If you use two hot plates of the same size, can you assume that the hot plate that can boil the one gallon of water first is at the higher temperature? Which lettered example above supports your answer?

3. If you use two hot plates at the same temperature, can you assume that the hot plate that can boil the one gallon of water first is larger? Which lettered example above supports your answer?

4. If you use two hot plates of different sizes, can you assume that the hot plate that can boil the one gallon of water first is at a higher temperature? Which lettered example above supports your answer?

5. Two students are discussing their answer to question 4:

Student 1: *In 1d, the hot plate on the left boils the water quicker than the one on the right even though it is smaller. The hot plate's higher temperature is what makes it boil the water more quickly.*

Student 2: *But the size of the hot plate also plays a part in making it boil fast. If the hot plate on the left were the size of a penny, the water would take really long time to boil. I bet that if the size difference were great enough, the one at the lower temperature could boil the water first.*

Do you agree or disagree with either or both of the students? Why? (If you agree with part of one, be sure to state which part and explain why!)

The time for the water to boil is determined by the rate at which the hot plate transfers energy to the pot (i.e., the POWER of the hot plate). This rate is related to both the temperature and the size of the hot plate. For stars, the rate at which energy is given off (the POWER) is called **luminosity** (see last half of section 11.1.3 in the textbook). Similar to the above example, a star's luminosity can be increased by:

- increasing its temperature; and/or
- increasing its surface area (or size).

Check! This relationship between luminosity, temperature and size allows us to make comparisons between stars. **Based on the paragraph above, review your previous answers and make any needed changes!**

6. If two hot plates have the same temperature and one boils the one-gallon pot of water more quickly, what can you conclude about the sizes of the hot plates? If one is larger, tell which one.

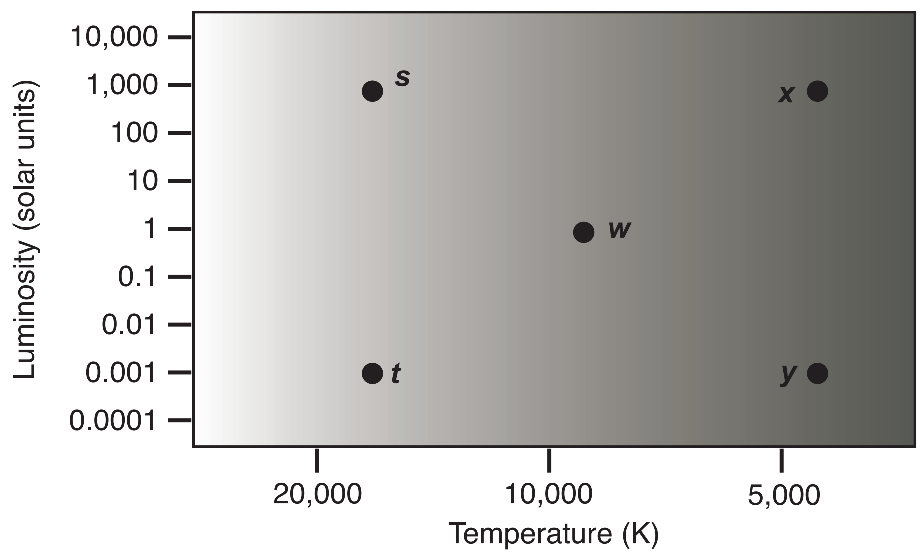
7. Likewise, if two stars have the same surface temperature and one is more luminous, what can you conclude about the sizes of the stars? If one is larger, tell which one. Why should your answer to this question be the *same* as your answer to question #6?

8. If two stars have the same surface temperature and are the same size, which star, if either, is more luminous? Explain your answer.

9. If two stars are the same size but one has a higher surface temperature, which star, if either, is more luminous? Explain your answer AND include in your answer which hot plate pair in question #1 corresponds to this situation.

Part 2: Application to the H-R Diagram

The graph below plots the luminosity of a star on the vertical axis against the star's surface temperature on the horizontal axis. This type of graph is called an H-R diagram (see p. 262 in the textbook). Use the H-R diagram below and the relationship between a star's luminosity, temperature and size (as described Part 1) to answer the following questions concerning the stars labeled ***s*** – ***y***. Note the temperature (X) axis DEcreases to the right.



10. Stars ***s*** and ***t*** have the same surface temperature. Given that Star ***s*** is actually much more luminous than Star ***t***, what can you conclude about the size of Star ***s*** compared to Star ***t***? **Explain your answer!**
    Also: Which hot plate pair in question #1 corresponds to this situation?

11. Star ***s*** has a greater surface temperature than Star ***x***. Given that Star ***x*** is actually just as luminous as Star ***s***, what can you conclude about the size of Star ***x*** compared to Star ***s***? **Explain your answer!**
    Also: Which hot plate pair in question #1 corresponds to this situation?

12. Based on the information presented in the H-R diagram, which star is larger, ***x*** or ***y***? Explain. (Note the similarity to the scenario in question #10!)

13. Based on the information presented in the H-R diagram, which star is larger, ***y*** or ***t***? Explain. (Note the similarity to the scenario in question #11!) **Two more on next page! →**

14. On the H-R diagram, draw a "***z***" at the position of a star smaller in size than Star ***w*** but with the same luminosity. Explain your reasoning.

15. Why can't you compare the size of Star ***s*** to that of Star ***w***?

14C = 4.75, 13C = 4.5, 12C = 4.0, 11C = 3.75, 10C = 3.5, 9C = 3.0, 8C = 2.75, 7C = 2.5, 6C = 2.0

3.10 Cosmos: "The Lives of the Stars"

Hand in at the end of the video

All of this material is also found in the textbook (ch. 12 & 13) In the first part of the lesson, Carl Sagan gives you some perspective on what infinity is so that you have some reference for the "infinitesimally" small scales of the atomic nucleus and the true infinities of warped space around black holes. Then Sagan talks about the structure of the chemical elements.

1. What particle in an atom's **nucleus** distinguishes the chemical elements from each other?

2. The number of these particles in hydrogen: _____; helium: _____; carbon: _____; oxygen: _____; uranium: _____.

3. How can the protons in the nucleus stick together despite their mutual electrical repulsion?

   When can this force operate?

4. What conditions are needed to create helium, carbon, oxygen, etc. and where are such conditions found?

5. Do stars form far from other stars or in clusters?

6. Stars can be characterized by whatever holds them up against the relentless compression of gravity.
   What holds a regular star up?

7. What holds a white dwarf up?

   Mass of a white dwarf __________. Diameter of a white dwarf __________

8. What makes the nuclear force to hold a neutron star up?

   Mass of a neutron star __________. Diameter of a neutron star __________

9. What holds a black hole up?

   Mass of a black hole __________. Diameter of a black hole __________

10. When will our Sun become a red giant and why will its outer layers expand and cool to be only "red hot"?

11. At the <u>**end**</u> of the Sun's life, what will happen to the outer layers?

    What will the core become and how dense will it be?

O V E R

12. Where did the carbon in your cells come from (what star life stage)?

    Where did the gold in our banks come from (what star life stage)?

13. What happens in a *supernova explosion*?

14. What stars will have a supernova explosion at their death?

15. What is the diameter, mass, and density of a neutron star?

16. What is a *pulsar*?

    How is it able to produce the rapid flashes of light?

17. What is the path of light in weak gravity like the Earth's?
    What is the path of light in strong gravity with billions of Earth gravities?

18. What form of electromagnetic radiation is used to discover possible black holes?

19. In what type of star systems are black holes discovered?

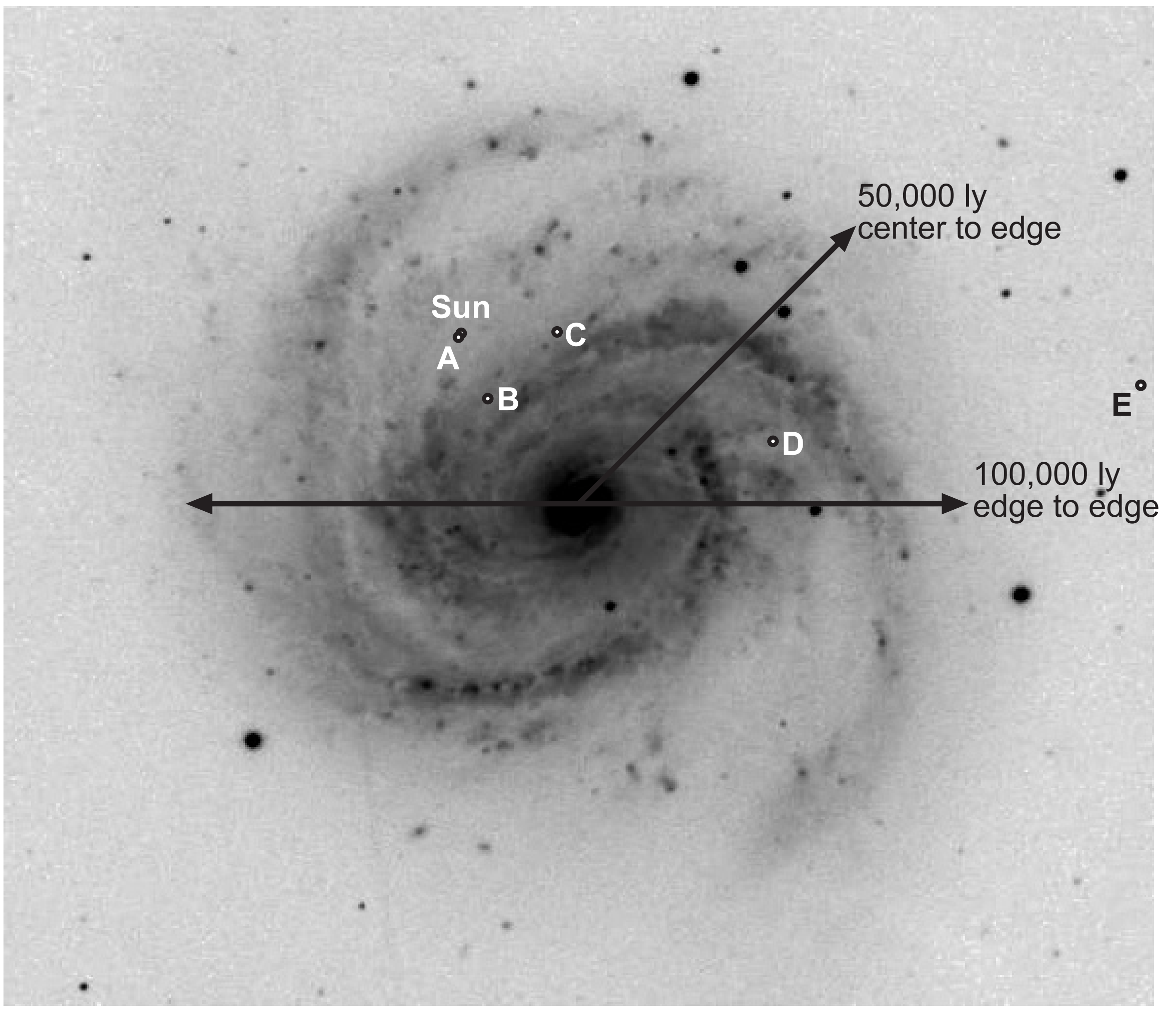
20. What does Einstein's theory of **General Relativity** say happens to the fabric of space-time around a strong local gravity source?

Every 4 / = 0.5; every 4 O = 1;
4 / ⇒ 4.5, 8 / ⇒ 4, 12 / ⇒ 3.5, 16 / ⇒ 3, etc.

3.11 Milky Way Scales tutorial

Courtesy of Adams, Prather, Slater and CAPER Team

This tutorial will give you a better understanding of the size of the Milky Way Galaxy by investigating the distances to objects with the Galaxy and to other objects in the Universe. This is a picture of M100, a spiral galaxy similar to the Milky Way. Because we are located within the Milky Way, we are unable to take a picture of our entire galaxy from the outside. Let's assume that this picture represents our Milky Way Galaxy and has the dimensions labeled below. **Note that in this picture, 1 centimeter (cm, about a pinky width) represents 10,000 light years (ly); equivalently you can use 1 millimeter (mm) to represent 1,000 light years (ly).** This 1cm blank: _____ = 10,000 light years; this 1mm blank: _ = 1000 light years.



1. The Sun's position in the Milky Way is shown in the picture above. Recall that 1.0 cm represents 10,000 ly. The A open-circle dot is almost entirely on top of the open-circle dot for the Sun so the Sun dot may be hard to see in your copy. **Fill in the blanks for distances of the dots *from the Sun*:** A dot: __________; B dot: __________; C dot: __________; galaxy center: __________; D dot: __________; E dot: __________.

2. The table lists five bright stars in the night sky. Write the letter of the open-circle dot (A, B, C, D, or E) from the picture above that best represents the location of each star. **You can use letters more than once.** Recall that 1 mm represents 1,000 ly = _.

Star	**Distance from Sun (in light years)**	**Letter**
Sirius	9	
Vega	26	
Spica	260	
Rigel	810	
Deneb	1,400	

3. We normally consider Deneb to be a bright but distant star at 1,400 ly away. Compared to the size (diameter) of our galaxy, is Deneb truly distant? Explain your reasoning.

4. Are the stars from question 2 inside or outside the Milky Way Galaxy? Explain your reasoning.

5. The table below lists three Messier objects and their distances from the Sun. Write the letter of the open-circle dot (A, B, C, D, or E) from the picture on the previous page that best represents the location of each object. You can use letters more than once.

Messier Object	**Distance from Sun (in light years)**	**Letter**
M 45 Open Cluster (Pleiades)	400	
M 1 (Crab Nebula)	6500	
M 71 Globular Cluster	12,700	

6. Are these Messier objects part of the Milky Way? Explain your reasoning.

7. The Crab Nebula has a width of about 11 light years. If you wanted to accurately draw the Crab Nebula on your diagram, would you use a small blob ("blob" is anything larger than 0.5 cm) or a tiny dot at the location you indicated? Explain your reasoning. (Note: the open-circle dots marking the locations on the picture are 1 mm across.)

8. The Sun is much smaller than a nebula (indeed, the entire solar system is smaller than a nebula!). The Sun's location is represented by an open-circle dot in the picture. Is this filled-circle dot too small, too large or just the right size to represent the size of the Sun on the picture? Explain your reasoning.

9. The Milky Way Galaxy is one of the largest galaxies in a group of nearby galaxies called the Local Group. The following table lists the distances to the centers of three Local Group galaxies. Draw a dot on your picture (if possible) to represent the center of each galaxy. Don't worry about the direction (left, right, up, or down) for the LMC and M 31; just place a dot at an appropriate distance from the Sun.

Galaxy	**Distance from Sun (in light years)**
Sagitarrius Dwarf Elliptical Galaxy (SagDEG) —closest galaxy to Milky Way located in the *same direction* as the galactic center, so draw a line from the Sun dot through the galaxy center to get the direction of SagDEG	80,000
Large Magellanic Cloud (LMC)	160,000
Andromeda Galaxy (M 31)	2,500,000

Do any of these galaxies fit on the page? Which one(s)?

10. The objects in question 9 are all visible in the night sky from Earth. Are these objects inside or outside the Milky Way? Explain your reasoning. (Use DISTANCE in your reasoning!)

11. SagDEG is approximately 11,000 ly across. Is this galaxy better represented on your diagram by a small blob or tiny dot (see question #7)? Explain your reasoning, and make an appropriate sketch to represent the galaxy.

12. Within the Local Group, the two largest galaxies are the Milky Way and Andromeda galaxies. From question 9, we saw that the Andromeda Galaxy was about 2,500,000 ly from us. On the picture, this spot would be 250 cm (about 2.5 meter sticks, or over 2.5 big steps) away from the dot representing the Sun.

    The nearest group of galaxies to us (not counting our own Local Group) is the Virgo Cluster, about 60,000,000 ly away. How many centimeters away would this cluster be on your picture? How many meters away would this be?

Blank Page

3.12 Looking at Distant Objects tutorial

Courtesy of Adams, Prather, Slater and CAPER Team

Imagine that you have received six pictures of six different children who live near six of the closest stars to the Sun. Each picture shows a child on his or her 12th birthday. The pictures were each broadcast directly to you (using a satellite) on the day of the child's birthday. Note the abbreviation "ly" is used below to represent a **light year**.

- Juan lives on a planet orbiting Ross 154, which is 9.7 ly from the Sun.
- Peter lives on a planet orbiting Barnard's Star, which is 5.9 ly from the Sun.
- Celeste lives on a planet orbiting Sirius, which is 8.6 ly from the Sun.
- Savannah lives on a planet orbiting Alpha Centauri, which is 4.4 ly from the Sun.
- Natalie lives on a planet orbiting Epsilon Eridani, which is 10.5 ly from the Sun.
- Alberto lives on a planet orbiting Procyon, which is 11.4 ly from the Sun.

1. Describe in detail what a light year is. Is it an interval of time, a measure of length or an indication of speed? It can only be ONE of these quantities.

2. Which child lives closest to the Sun? How far away does he or she live?

3. What was the greatest amount of time that it took for any one of the pictures to travel from the child to you?

4. If each child was 12 years old when he or she sent his or her picture to you, how old was each of the children when you received their picture? (Don't round and include the decimal fraction.)

   Juan _______ Peter _______ Celeste _______

   Savannah _______ Natalie _______ Alberto _______

5. Is there a relationship between the current age of each child and his or her distance away from Earth? If so, describe this relationship: The older the child, the _______ the distance.
   Circle one: smaller equal greater

6. Imagine that the six pictures were broadcast by satellite to you and that they all arrived at exactly the same time. For this to be true, does that mean that all of the children sent their pictures at the same time? If not, which child sent his or her picture first and which child sent his or her picture last?

7. The telescope image at right is of the Andromeda Galaxy which is located 2.5 million ly away from us. Is this an image showing how the Andromeda Galaxy looks right now, how it looked in the past or how it will look in the future? Explain your reasoning.

8. Imagine that you are observing the light from a distant star that was located in a galaxy 100 million ly away from you. By analysis of the starlight received, you are able to tell that the image we see is of a 10 million year old star. You are also able to predict that the star will have a total lifetime of 50 million years, at which point it will end in a catastrophic supernova.

   (a) How old does the star appear to us here on Earth?

   (b) How long will it be before we receive the light from the supernova event?

   (c) Has the supernova already occurred? If so , when did it occur?

9. Imagine that you take images of two main sequence stars that have the same mass (therefore, same spectral type). From your observations, both stars *appear* to be the same age. Consider the following possible interpretations that could be made from your observations.

   (a) Both stars are the same age and the same distance from you.
   (b) Both stars are the same age but at different distances from you.
   (c) The stars are actually different ages but at the same distance from you.
   (d) Star that is closer to you is actually the older of the two stars.
   (e) The star that is farther from you is actually the older of the two stars.

   How many of the five choices (a, b, c, d, e) are possible? Which ones? Explain your reasoning. [Hint: make sure your choice(s) will work for #4, #5 and #6! Would your choice(s) work for Savannah and Alberto?]

9C = 3.0, 8C = 2.75 unless #9 = 2.5, 7C = 2.25, 6C = 2.0, 5C = 1.75, 4C = 1.5

3.13 Hubble Law — Uniform Expansion?

In this worksheet you will get some experience with a uniformly expanding space and how it gives rise to the **Hubble Law**. The **Hubble Law** states that the speed of a galaxy's (or galaxy cluster's) recession from us is directly proportional to its distance from us. With uniform expansion, the patterns of motion are such that the separations between any two galaxies (or galaxy clusters) increases by the same factor in the same time interval. Furthermore, with a uniform expansion, any observer in any "home" galaxy should derive the same Hubble Law at the same time interval after the start of the expansion.

Directions

The attached diagrams represent the boundaries and locations of 30 clusters of galaxies. The scale of the diagrams is 1 millimeter = 10 million light years (MLY), so 1 centimeter = 100 MLY and 10 cm = 1 billion light years (BLY). The time interval between these two "snapshots" is 3 billion years.

1. Select one of the numbered clusters on the "Start" figure for your "home" cluster and find the distances to **at least** 5 other numbered galaxy clusters with the attached "Start D" distance table. Enter these measurements in the "Hubble Table A". The distance table is read like the mileage charts on maps: (a) Find your home cluster in the far left column; (b) Run your finger along that home cluster's row until you come to the column of the other galaxy and read off the number in the cell. For example, the distance between clusters 4 and 20 is at the intersection of the row for cluster 4 and the column 20 = 48 mm.

   You should choose galaxies with a wide range of distances. For example, a couple of close galaxies, a couple of medium distance galaxies, and a couple of far galaxies.

2. Make the same measurements (for the same numbered clusters) on the "End" figure (using the same "home" cluster. Enter the measurements in the table and convert them to distances in MLY. These are the distances to your standard clusters at the later time, T + 3 Byr.

3. Calculate the speed of each external galaxy cluster:
   speed = (change in distance)/(change in time)

   The time interval of 3 Byr makes the arithmetic easy to convert the speeds to kilometers/second: the distance change in millimeters = the speed in thousands of kilometers/second (e.g., distance change of 2.5 mm = 2,500 km/sec).

4. Plot your measured distances and speeds on "Hubble Plot A", with distance on the X-axis and speed on the Y-axis. Note that you must be consistent in which of the two distance measurements you use. In this worksheet, you will use the distances from the "End" figure (which is why you converted just the "End" distances to MLY). If the expansion is uniform, the points will lie on a straight line.

5. Draw a *straight* line through the origin (0,0 point) of your graph which passes approximately through as many of your data points as possible. Use a *straight* edge like a ruler!

6. Determine the slope of your Hubble Law in units of km/sec per MLY. This is your **Hubble constant**. Label the **Hubble constant** clearly.

7. Now select a *DIFFERENT* numbered cluster for your "home" cluster. Repeat steps 1–6 to determine the **Hubble constant** from this new home cluster. Enter your measurements and speeds in the "Hubble Table B" and plot your points on "Hubble Plot B".

Hubble Table A – Home Galaxy = _______

Galaxy No.	Start D (mm)	End D (mm)	End D (MLY)	End–Start D (mm)	speed (km/sec)

Hubble Table B – New Home Galaxy = _______

Galaxy No.	Start D (mm)	End D (mm)	End D (MLY)	End–Start D (mm)	speed (km/sec)

Follow-up Questions – these are the ones graded for pts. (1 pt each except #1)

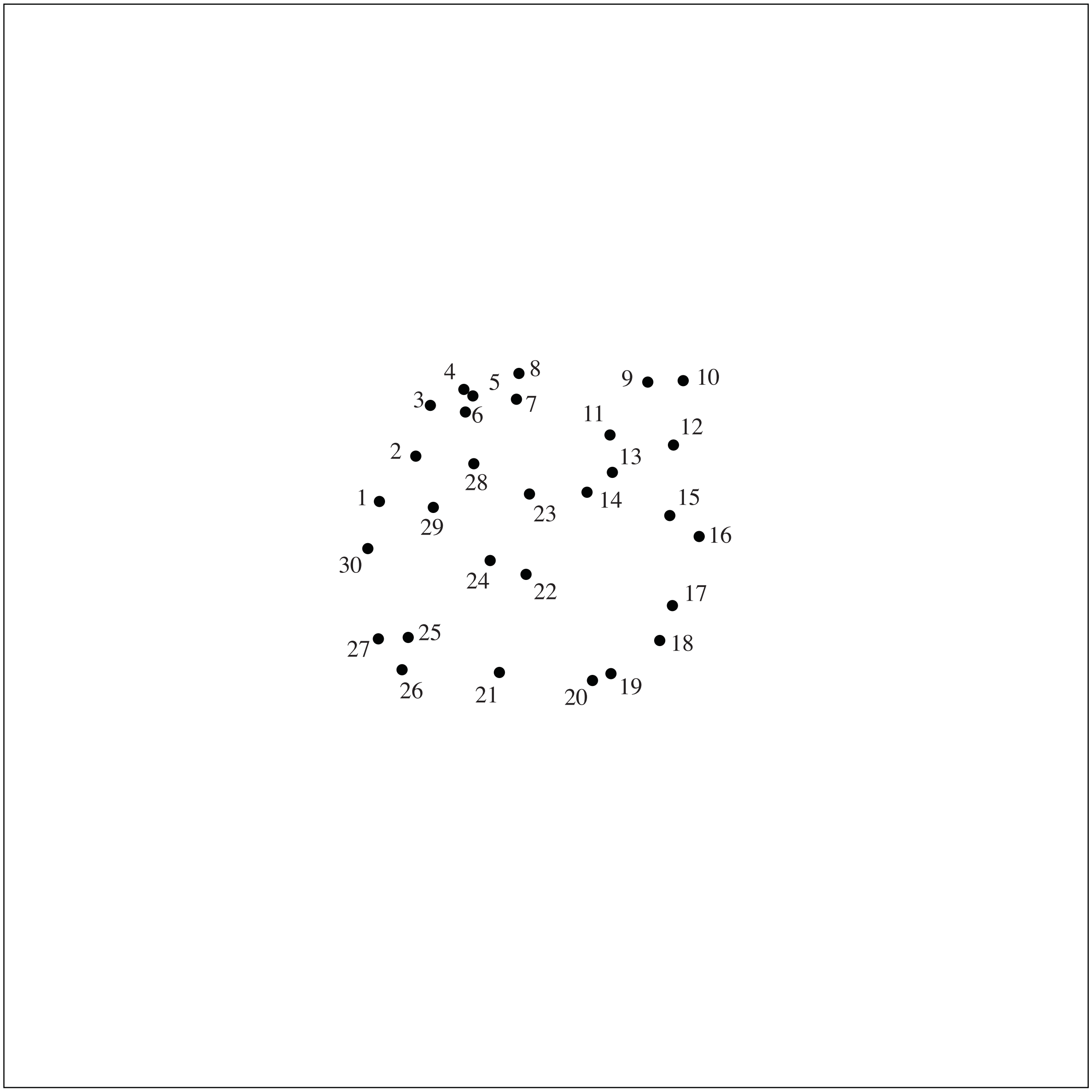
1. (2 pts) Fill in the slope blanks on the plot page and answer the question about accurate slope. Also: Did you derive the same value of the **Hubble constant** from your two different home galaxies? (Random measurement errors will mean slopes within 1.5 km/sec/Mly are equal.)

2. Calculate by what factor the same region of the Universe has expanded in the 3 Byr time interval between the "snapshots" by finding (End D mm)/(Start D mm) for 3 clusters and taking the average. Show work! Give factor for each cluster and the average.

3. In step 5, you were told to draw the line through the origin of the graph. Why should the line go through the origin? (Hint: see the top of p. 458 in the textbook.)

4. The sizes of the galaxy clusters represented by the small filled-circle dots in the two snapshots are the same. Was this a mistake? If yes, why is it a mistake? If no, why should the galaxy cluster sizes remain the same? [Hint: see p. 459 in the textbook (picture & text and margin note).]

Start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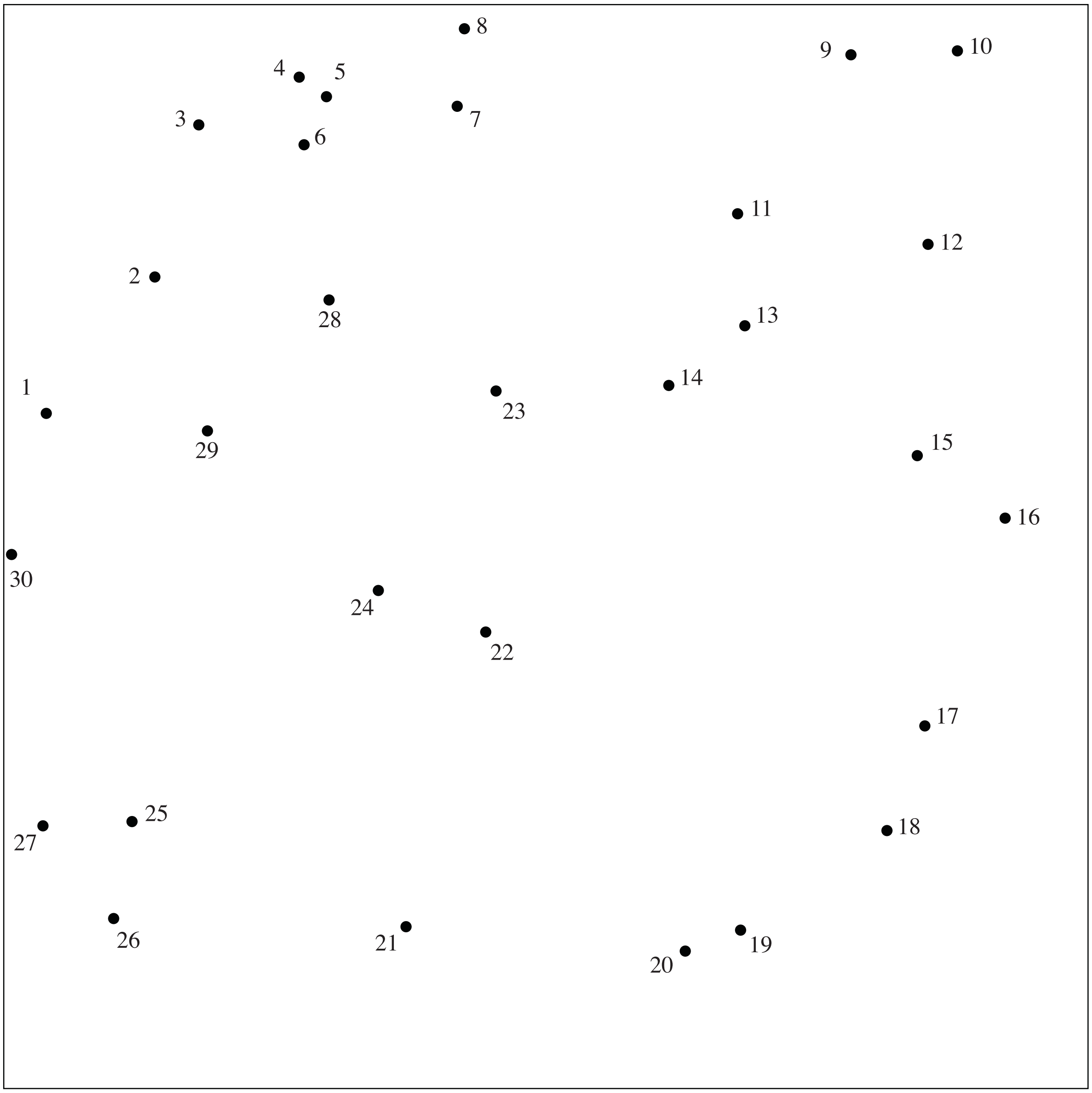
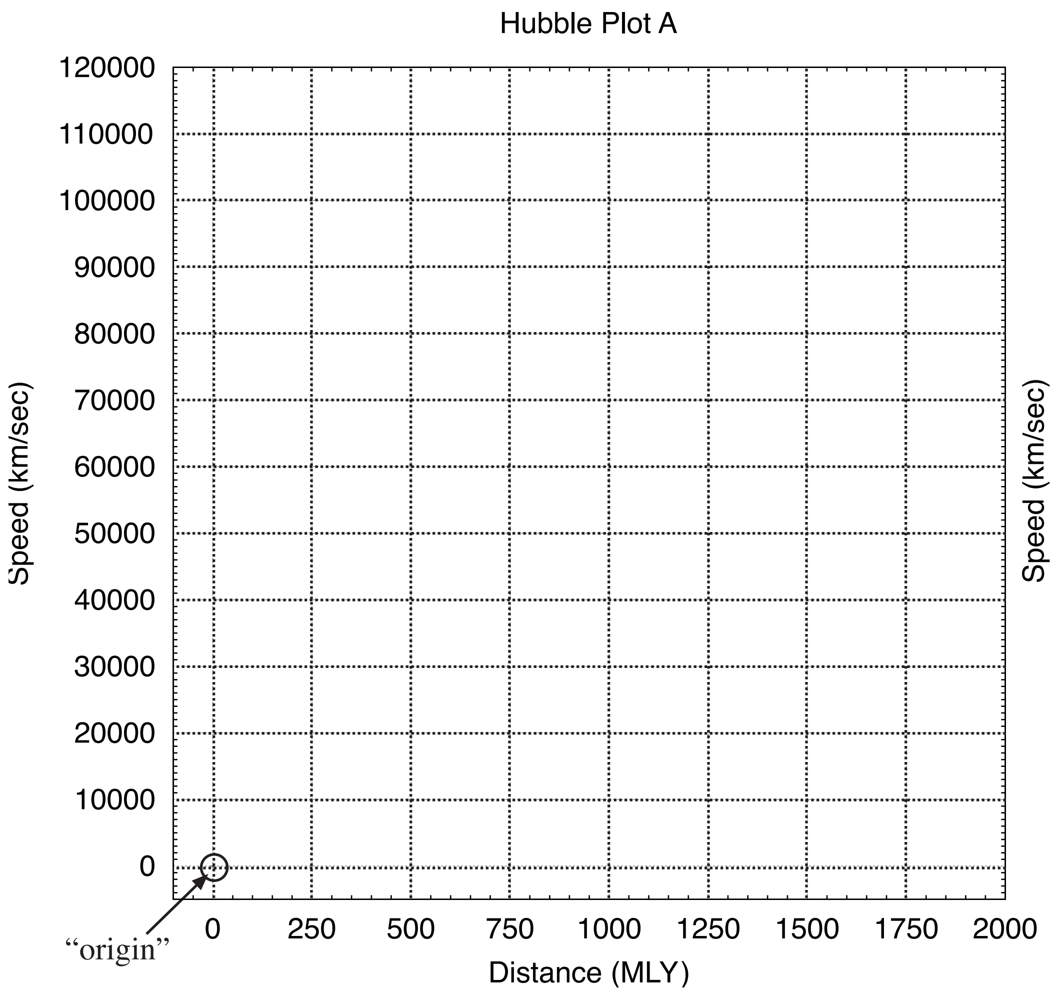
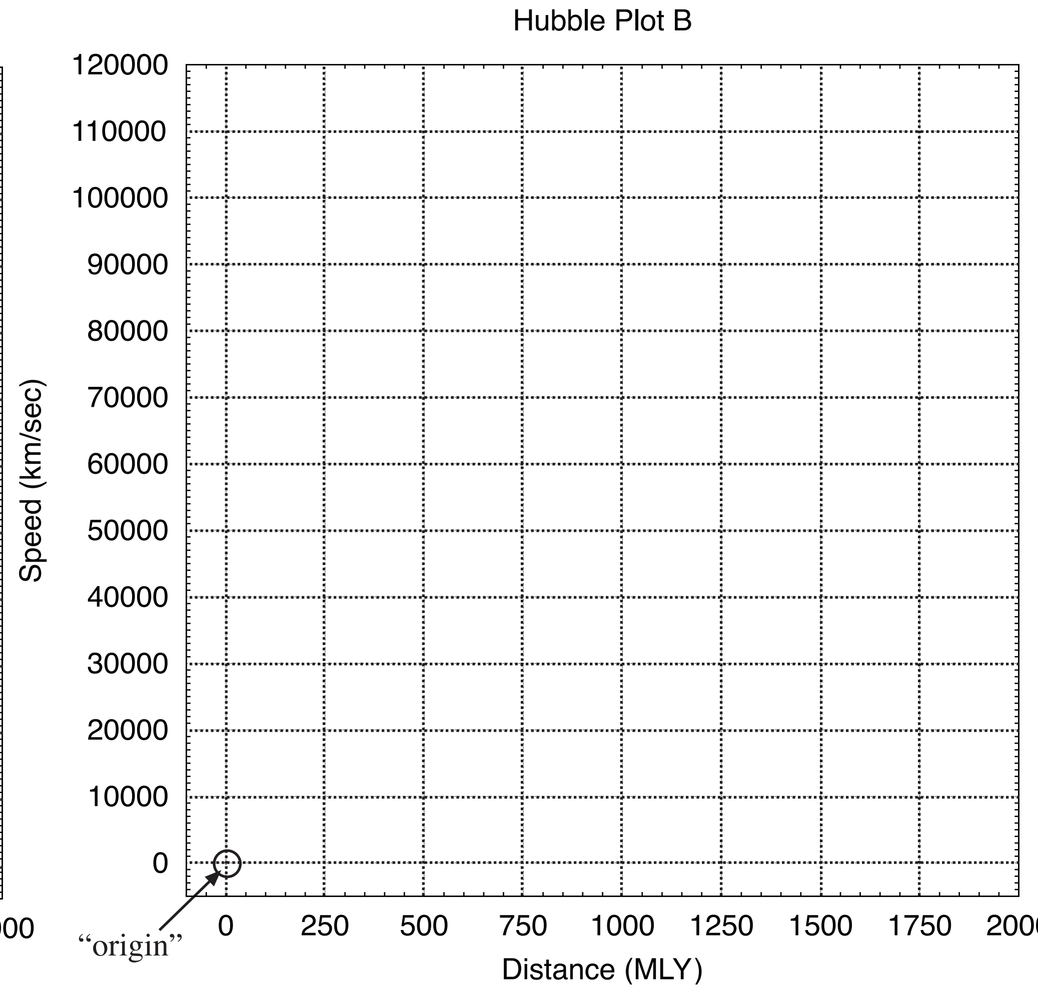
End -- 3 Byr Later







Slope graph A = __________ km/sec/Mly

Slope graph B = __________ km/sec/Mly

Each xtic is 50 MLY and each ytic is 1000 km/sec

If line goes through "origin", pick a cluster of **medium to great distance** that falls on the line and calculate slope = cluster's speed / cluster's distance. Why does using clusters of medium to great distances give a more accurate slope? [Hint: how does an uncertainty of 0.5mm in the dot distances for a small distance compare with an uncertainty of 0.5mm for a large distance? Compare (0.5mm/small distance mm) to (0.5mm/large distance mm).]

Hubble Law -- Uniform Expansion Example Calculation

In this example, I will use galaxy (cluster) 1 as my home galaxy and find the distance and speed for galaxy (cluster) 7.

- Start D (mm) for galaxy 7 is found from the table on p. 82 by using the first ROW (galaxy 1) and scanning over to the "7" COLUMN. Start D = 26 mm.
- End D (mm) for galaxy is found from the table on p. 83 in the same way as for the start distance. End D = 77 mm.
- End D (MLY) = End D mm * 10, so the End D for galaxy 7 is 77 * 10 = 770 million light years.
- End - Start D (mm) = 77 mm - 26 mm = 51 mm.
- Speed of the galaxies are found by multiplying the subtraction result by 1000, so galaxy 7 = 51 * 1000 = 51,000 km/sec.

Graphing Notes

- **Warning:** The zero, zero point ("origin" in math graphing lingo) is ***NOT*** the very bottom left corner! It is a little up and a little to the right of bottom left corner where the dotted lines intersect.
- Each tiny tic mark along the x-axis (DISTANCE) corresponds to 50 million light years.
- Each tiny tic mark along the y-axis (SPEED) corresponds to 1000 km/sec.
- ***IF*** you plot the points correctly, they will all fall on the same line. If you're sloppy, they won't.
- If a point is not on the line, then re-check your speed or distance calculation in the table—you made an arithmetic error.
- Calculate the slope of the line by finding the "rise over the run" = change in Y divided by the change in X. If your line goes through the zero, zero point (see warning note above!), pick a galaxy that falls on the line and divide its speed by its distance. That will be the slope of the line.
- ***IF*** you plot the points correctly and don't make any arithmetic errors in your table or slope calculation, the slope of the line in Hubble Plot A will equal the slope of the line in Hubble Plot B. If the slopes are not equal, re-check your arithmetic and the accuracy of your plotted points!

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last updated: November 26, 2007

Start D in millimeters
Column Galaxy to Row Galaxy

Galaxy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	9	16	21	21	19	26	29	44	49	36	45	35	31	44	48	47	47	43	42	31	25	23	19	21	26	21	15	8	7
2	9	0	8	12	12	10	17	20	37	42	29	39	30	26	39	44	45	46	44	43	35	24	18	19	27	32	28	9	8	16
3	16	8	0	6	7	5	13	14	33	38	27	37	29	27	40	45	47	49	49	48	42	29	20	25	35	40	36	11	15	24
4	21	12	6	0	2	3	8	9	28	33	23	33	26	24	36	42	45	48	48	48	43	29	19	26	38	43	40	11	18	28
5	21	12	7	2	0	3	7	8	26	32	21	31	24	22	35	40	44	46	47	47	42	28	17	25	38	43	39	10	18	28
6	19	10	5	3	3	0	8	10	28	33	22	32	24	22	34	40	43	45	45	45	40	26	16	23	35	40	37	8	15	25
7	26	17	13	8	7	8	0	4	20	25	15	25	18	18	29	34	39	42	44	44	41	26	14	25	39	44	42	12	21	32
8	29	20	14	9	8	10	4	0	19	25	17	26	21	21	31	37	42	45	47	48	45	30	18	29	43	48	45	15	24	35
9	44	37	33	28	26	28	20	19	0	5	10	10	15	19	20	25	34	39	44	46	49	34	25	36	53	57	56	29	37	49
10	49	42	38	33	32	33	25	25	5	0	14	10	17	22	20	24	34	39	45	47	52	38	29	40	57	61	60	34	42	54
11	36	29	27	23	21	22	15	17	10	14	0	10	6	9	15	20	27	32	36	37	39	25	15	26	43	47	46	21	29	40
12	45	39	37	33	31	32	25	26	10	10	10	0	10	15	11	14	24	30	36	38	43	30	23	33	49	53	53	30	37	49
13	35	30	29	26	24	24	18	21	15	17	6	10	0	5	11	16	22	26	30	32	35	20	13	23	40	43	43	21	27	39
14	31	26	27	24	22	22	18	21	19	22	9	15	5	0	13	18	21	25	28	28	30	15	9	18	35	39	38	18	23	34
15	44	39	40	36	35	34	29	31	20	20	15	11	11	13	0	5	14	19	25	27	35	23	21	28	43	47	48	31	36	46
16	48	44	45	42	40	40	34	37	25	24	20	14	16	18	5	0	11	17	25	27	36	27	26	32	46	49	51	36	40	50
17	47	45	47	45	44	43	39	42	34	34	27	24	22	21	14	11	0	6	14	16	28	23	27	28	40	42	45	37	39	47
18	47	46	49	48	46	45	42	45	39	39	32	30	26	25	19	17	6	0	9	12	25	22	30	28	38	39	42	39	40	46
19	43	44	49	48	47	45	44	47	44	45	36	36	30	28	25	25	14	9	0	3	17	20	30	25	31	31	35	38	37	41
20	42	43	48	48	47	45	44	48	46	47	37	38	32	28	27	27	16	12	3	0	14	19	30	24	29	29	33	37	35	39
21	31	35	42	43	42	40	41	45	49	52	39	43	35	30	35	36	28	25	17	14	0	15	27	17	15	15	19	32	27	27
22	25	24	29	29	28	26	26	30	34	38	25	30	20	15	23	27	23	22	20	19	15	0	12	6	20	24	24	18	17	24
23	23	18	20	19	17	16	14	18	25	29	15	23	13	9	21	26	27	30	30	30	27	12	0	12	28	33	32	10	15	26
24	19	19	25	26	25	23	25	29	36	40	26	33	23	18	28	32	28	28	25	24	17	6	12	0	17	21	21	15	12	19
25	21	27	35	38	38	35	39	43	53	57	43	49	40	35	43	46	40	38	31	29	15	20	28	17	0	5	4	28	20	15
26	26	32	40	43	43	40	44	48	57	61	47	53	43	39	47	49	42	39	31	29	15	24	33	21	5	0	6	33	25	19
27	21	28	36	40	39	37	42	45	56	60	46	53	43	38	48	51	45	42	35	33	19	24	32	21	4	6	0	30	21	14
28	15	9	11	11	10	8	12	15	29	34	21	30	21	18	31	36	37	39	38	37	32	18	10	15	28	33	30	0	9	20
29	8	8	15	18	18	15	21	24	37	42	29	37	27	23	36	40	39	40	37	35	27	17	15	12	20	25	21	9	0	12
30	7	16	24	28	28	25	32	35	49	54	40	49	39	34	46	50	47	46	41	39	27	24	26	19	15	19	14	20	12	0

Find the galaxy of interest in the far left column. The distances (in mm) to the rest of the galaxies are in that row (like the mileage charts on maps).

End D in millimeters
Column Galaxy to Row Galaxy

Galaxy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	26	49	63	64	56	77	86	133	148	108	135	106	94	131	145	140	141	130	126	94	74	68	57	63	77	62	46	24	22
2	26	0	24	37	37	30	52	60	110	126	88	117	89	79	118	133	134	138	132	129	105	73	54	58	82	97	84	26	24	47
3	49	24	0	17	20	16	39	43	99	115	82	111	88	81	119	135	142	148	146	144	125	88	60	75	105	120	108	33	46	71
4	63	37	17	0	5	10	24	26	83	99	69	98	77	72	109	125	136	144	145	144	129	88	56	78	115	130	119	34	55	84
5	64	37	20	5	0	8	20	23	79	95	64	93	72	67	104	120	131	139	140	140	126	84	51	75	113	128	118	31	53	84
6	56	30	16	10	8	0	24	30	83	99	66	95	72	66	104	120	128	136	135	134	119	78	47	68	105	120	110	24	45	76
7	77	52	39	24	20	24	0	12	60	76	45	74	54	53	87	103	117	127	131	132	124	79	43	74	118	133	125	35	62	95
8	86	60	43	26	23	30	12	0	58	74	50	77	62	62	94	110	126	136	142	143	136	91	55	86	129	144	136	46	72	104
9	133	110	99	83	79	83	60	58	0	16	29	31	44	57	61	74	102	117	133	137	147	103	74	108	158	171	168	87	112	147
10	148	126	115	99	95	99	76	74	16	0	41	29	52	67	61	71	102	118	136	142	156	113	86	119	170	182	181	102	127	161
11	108	88	82	69	64	66	45	50	29	41	0	29	17	28	45	61	82	96	108	111	118	74	45	78	129	142	139	63	86	121
12	135	117	111	98	93	95	74	77	31	29	29	0	30	44	32	43	73	89	107	113	129	89	69	98	148	159	159	91	112	146
13	106	89	88	77	72	72	54	62	44	52	17	30	0	15	33	49	66	79	91	95	104	60	39	68	119	130	130	63	82	116
14	94	79	81	72	67	66	53	62	57	67	28	44	15	0	39	54	64	75	83	85	91	46	26	54	104	116	115	53	70	102
15	131	118	119	109	104	104	87	94	61	61	45	32	33	39	0	16	41	57	76	82	105	70	64	84	130	140	143	92	107	137
16	145	133	135	125	120	120	103	110	74	71	61	43	49	54	16	0	34	50	74	81	109	80	79	95	139	147	152	107	121	150
17	140	134	142	136	131	128	117	126	102	102	82	73	66	64	41	34	0	17	41	50	84	68	82	85	120	126	134	110	117	140
18	141	138	148	144	139	136	127	136	117	118	96	89	79	75	57	50	17	0	27	35	74	67	89	85	114	117	127	116	119	138
19	130	132	146	145	140	135	131	142	133	136	108	107	91	83	76	74	41	27	0	9	50	59	89	75	93	94	106	113	110	123
20	126	129	144	144	140	134	132	143	137	142	111	113	95	85	82	81	50	35	9	0	42	57	89	71	86	86	99	112	106	118
21	94	105	125	129	126	119	124	136	147	156	118	129	104	91	105	109	84	74	50	42	0	46	82	51	44	44	57	95	80	82
22	74	73	88	88	84	78	79	91	103	113	74	89	60	46	70	80	68	67	59	57	46	0	36	17	60	71	73	55	52	72
23	68	54	60	56	51	47	43	55	74	86	45	69	39	26	64	79	82	89	89	89	82	36	0	35	85	98	95	29	44	77
24	57	58	75	78	75	68	74	86	108	119	78	98	68	54	84	95	85	85	75	71	51	17	35	0	51	63	62	44	35	56
25	63	82	105	115	113	105	118	129	158	170	129	148	119	104	130	139	120	114	93	86	44	60	85	51	0	15	13	84	60	44
26	77	97	120	130	128	120	133	144	171	182	142	159	130	116	140	147	126	117	94	86	44	71	98	63	15	0	18	99	75	57
27	62	84	108	119	118	110	125	136	168	181	139	159	130	115	143	152	134	127	106	99	57	73	95	62	13	18	0	90	64	41
28	46	26	33	34	31	24	35	46	87	102	63	91	63	53	92	107	110	116	113	112	95	55	29	44	84	99	90	0	27	61
29	24	24	46	55	53	45	62	72	112	127	86	112	82	70	107	121	117	119	110	106	80	52	44	35	60	75	64	27	0	35
30	22	47	71	84	84	76	95	104	147	161	121	146	116	102	137	150	140	138	123	118	82	72	77	56	44	57	41	61	35	0

Find the galaxy of interest in the far left column. The distances (in mm) to the rest of the galaxies are in that row (like the mileage charts on maps).

3.14 Origins: The Birth of the Universe

At the beginning of the video Neil deGrasse Tyson describes the beauty of the night sky and introduces the most basic questions about the cosmos. Has the universe always been here? Did it have a beginning? He notes that our understanding of the universe has been transformed again and again. One classic example is replacement of the Steady State theory with the Big Bang theory.

1. What is the Steady State theory?

2. What problem was there with the early telephone calls relayed by satellites such as Telstar?

3. What band(s) of the electromagnetic spectrum are used for satellite communication?

4. What did Wilson and Penzias find when they pointed their large radio horn antenna at empty space?

5. What did Bob Dicke at Princeton believe about the early universe and what should still be detectable from that early time?

6. What does the Big Bang theory say about the universe's beginning?

7. What happens to the light as the universe expands and what form of EM radiation is that light now?

8. What is the cosmic microwave background radiation first detected by Pensias and Wilson?

9. What problem was there with the Big Bang theory?

10. What is needed in the early universe to create the cosmic structure we see today?

11. How would that show up in the microwave glow?

12. But instead what did we see in the microwave glow?

    Finally, after two years of gathering data above the Earth's atmosphere, the COBE satellite found the signatures in the microwave glow at the 1 part in 100,000 level.

13. In the false color image of the microwave glow, what do the blue colors correspond to and what happens to those areas of the microwave universe map?

14. What limitation did COBE have?

15. What information is encoded in the microwave background that requires higher resolution to find it?

16. What in our atmosphere blocks a lot of the microwaves from the cosmic background and how high up do you need to get to do the microwave background imaging?

17. What do the brighter, hotter spots of the microwave background correspond to?

18. What will gravity transform those spots into?

19. How long after the Big Bang was the light created we now see as the cosmic microwave background?

20. When did the expansion of the universe start (the Big Bang)?

21. What was happening to the light in the very early universe?

22. What is happening to the universe as it expands?

23. What happened at 380,000 years after the Big Bang so the light could flash free?

24. What two types of atoms were in the early universe?

25. Where did the atoms heavier than hydrogen and helium come from?

26. How much of the star's life is spent making the atoms heavier than helium?

27. What type of atom is the basis, the foundation, for life (organic chemistry)?

28. What happens when iron is created in the star's core?

29. What types of atoms can be created in the outrageous energies of a supernova (overcoming the iron barrier)?

30. What does each generation of stars do to make life possible?

31. How large are each of the little nodules in the Eagle Nebula and what is found inside of them?

    Galaxies provide the gravity to keep the heavy elements blown out in supernova explosions from dispersing too far into the rest of the universe so that they can accumulate to "concentrate the broth" for life to eventually arise.

32. How do astronomers, like Sandra Faber, determine the concentration of the elements needed for life in other galaxies?

33. What has Faber's team found about the concentration of elements needed for life in other galaxies?

34. Where are habitats for life found?

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