Name: ________________________________Lab Day & Time: ____________________________

Measurements and Numbers in Astronomy

Astronomy is a branch of science. You will be exposed to some numbers expressed in SI units, large and small numbers, and some numerical operations such as addition / subtraction, multiplication / division, and ratio comparison.
Let's watch part of an IMAX movie called Cosmic Voyage.
https://www.youtube.com/watch?v=xEdpSgz8KU4

Powers of 10

In Astronomy, we deal with numbers that describe very large and very small things. For example, the mass of the Sun is 1,990,000,000,000,000,000,000,000,000,000 kg and the mass of a proton is 0.000,000,000,000,000,000,000,000,001,67 kg. Such numbers are very cumbersome and difficult to understand. It is neater and easier to use the scientific notation, or the powers of 10 notation.

For large numbers:

1	no zero	$= 10^{0}$
10	1 zero	$= 10^{1}$
100	2 zero	$= 10^{2}$
1000	3 zero	$= 10^{3}$

For small numbers:

0.1 = 1/10	Divided by 10	$=10^{-1}$
0.01 = 1/100	Divided by 100	$=10^{-2}$
0.001 = 1/1000	Divided by 1000	$=10^{-3}$

Example used on real numbers:
1,990,000,000,000,000,000,000,000,000,000 kg -> $1.99X10^{30}$ kg
0.000,000,000,000,000,000,000,000,001,67 kg -> $1.67X10^{-27}$ kg
See how much neater this is! Now write the following in scientific notation.

1. 40,000	
2. 9,000,000	
3. 12,700	
4. 380,000	
5. 0.017	
6. 0.003	
7. 0.0000005	
8. 0.00205	

Some powers of 10 have names.

	10^{3} = kilo, 'k'	10^{6} = million, M	10^{9} = billion or giga, 'G'
10^{-2} = centi, 'c'	10^{-3} = milli, 'm'	10^{-6} = micro, 'μ'	10^{-9} = nano, 'n'

Arrange these distances in order from shortest to longest.
1 meter, 1 kilometer, 1 millimeter, 1 centimeter

____

Name: ________________________________Lab Day & Time: ____________________________

Comparing numbers

It is important to be able to look at numbers and immediately recognize how they compare. For example, Earth is $5.792X10^{27}$ kg, and Mars is $0.65X10^{27}$ kg. First, which is more massive?

____

By how much? We compare by dividing the two numbers.

$$\frac{Mass_{Earth}}{Mass_{Mars}} = \frac{5.792 \times 10^{27}}{0.65 \times 10^{27}}$$

At this point, you should recognize that both numbers include 10^{27} so they will cancel out. All that is left over is 5.792/0.65. Once you are comfortable with decimals, you should realize that 5.792 is approximately 10 times more than 0.65. Therefore, Earth is 10 time more massive than Mars. Inputting the above in a calculator will return 8.91, which is close enough to 10. If you had divided the mass of Mars with the mass of Earth, you would have gotten a result that said "Mars is 8.91 times less massive than the Earth.".

With practice, these relationships will become second nature. This will help you immediately visualize relationships using numbers.

Fill in the blanks. Show all work. Here are some powers of 10 calculations to help.

$$\frac{10^m}{10^n} = 10^{(m-n)}, 10^m \times 10^n = 10^{(m+n)}$$

1	Distance of Earth to Sun = 1AU __________________ is ________________ times further from the Sun.	Distance of Jupiter to Sun = 5.2AU.
2	Sun's diameter = 1.4×10^6 km __________________'s diameter is ________________ times larger.	Earth's diameter = 1.3×10^4 km
3	Lifetime of a 25 $M_\odot$ star = $4X10^6$ years __________________ lives ________________ times longer.	Lifetime of the Sun = $10 X 10^9$ years
4	Mercury's orbital period = 88 Earth days __________________ takes _________________ times longer to orbit around the Sun.	Pluto's orbital period = 90,560 Earth days

Name: ________________________________Lab Day & Time: ____________________________

Astronomical Unit

Go to the west wall of the classroom where you see the solar system pictures.
What is the distance displayed under the Earth's picture? in both AU and km?

Is the distance between Earth& Sun always the same? Explain.

What is the definition of AU or astronomical unit?

Converting Units

Converting units is something we need to familiarize ourselves with, or we will end up like the loss of the Mars Orbiter in 1999 (look it up, it is an embarrassment to science). Here, we will practice some unit conversion. You will always be provided with the conversion factor. You can think about if your answer should be bigger or smaller number. For example, what if you were asked to convert 42 km to miles? 1 mile = 1.6 km. Since for each mile, you fit 1.6 km, you should recognize that your result in miles should result in a smaller number. So you should divide 42 km by the conversion factor.

$$42km \times \frac{1mile}{1.6km} = 26.25mile$$

Convert the following. Show all work and include the appropriate unit. This may be useful. 1AU = 1.5×10^8 km

1. 2AU -> _____________________km

2. 0.5AU -> ______________________km

3. 450,000,000km -> _______________________________AU

4. Mercury's average distance from the sun is 57,900,000km. This is ______________________AU

Name: ________________________________Lab Day & Time: ____________________________

5. Which planet in our Solar System has an average distance from the sun of 9.5 AU? What is this distance in km?

Light Year is the distance that light travels in vacuum in one year: 1 ly = 9.5×10^{12} km
Convert the following and show your work.

1. The brightest star in the night sky, Sirius, is 8.6 ly away. Convert this to km:

2. One of the nearest known potentially earth like exoplanet in Tau Ceti system is about 1.135×10^{14}km away. How far is the plant in light years?

3. If you are to send a text message to an intelligent creature who lives on that planet around TauCeti system, how long would it take for the message get there? Assume your text message will travel at speed of light. Explain your answer

4. If you assume the creature will reply back as soon as it receives the message, in what year will you hear back? Explain

If you are measuring a distance to a dwarf planet in Kuiper belt, what distance unit would you use?
AU LY

If you are measuring a distance to a star in Milky Way galaxy, what distance unit would you use?
AU LY

Name: ________________________________Lab Day & Time: ____________________________

Angular Measurements

Now we will explore basic conversion of angular units. You may be already familiar with the unit "degrees". There are smaller units to express smaller angles: arcminutes and arcseconds. They have the words "minute" and "second" but they are units of angle. The Babylonians who made calculations inherited the sexagesimal system from the Sumerians. So angles are counted as base 60 like the clock. 1^{o} = 60' (arcminutes) and 1' = 60" (arcseconds). For example, something can have an angle of 3 degree 54 arc minutes 27 arc seconds. This will be written as 3^{o} 54' 27".

In future labs, you will need to do several calculations where you must convert all arcminutes and arcseconds to degrees. Here, we will practice. As an example, let's convert the above to degrees. There are many ways to do this, and I will show you one of them.

Step 1: $27'' \times \frac{1'}{60''} = 0.45'$
Step 2: $54' + 0.45' = 54.45'$
Step 3: $54.45' \times \frac{1^\circ}{60'} = 0.9075^\circ$
Step 4: $3^\circ + 0.9075^\circ = 3.9075^\circ$
In summary, $3^\circ 54' 27'' = 3.9075^\circ$.

Convert the following to degrees. Show all work and units

1. 10^{o} 30' 15"

2. 0^{0} 6' 45"

Astronomers use angular measurement that can be used to pinpoint a direction as well as the apparent size of the object far away.

$$Angular\ Size\ (degrees) = Diameter \times \frac{57.3}{Distance}$$

In order for this equation to work, you must keep the units for the diameter and distance the same. Use this relationship to calculate the angular sizes of the Sun and the Moon. Show all work.

1. The Sun: Diameter = 1.392×10^{6} km, Distance = 1.496×10^{8} km

Angular size =

Name: ________________________________Lab Day & Time: ____________________________

2. The Moon: Diameter = 3.476×10^3km, Distance = 3.84×10^5 km

Angular size =

3. What do you notice about the angular size of the Sun and the Moon? Circle one.

The sun is much larger about the same the moon is much larger

Now we will find the angular size of your fist, thumb, and pinky.

In the front right of the classroom you will see three circles taped to the wall – these circles are marked Fist, Thumb, and Pinky.

a) Stretch your arm out straight in front of you. Make a fist.
b) Stand very close to the circle marked Fist. Your fist should not be big enough to cover the circle. Slowly back away until your fist just covers the entire circle.
c) Measure the distance from your feet to the circle on the wall. Record this distance in the table below.
d) Measure the diameter of the circle. Record the diameter in the table below. Make sure that the distance to the circle and the diameter of the circle are in the same units.
e) Using the equation on the top of this section, calculate the angular size of your fist. Show your work and record this on the table below.
f) Repeat steps a through e for your thumb and your pinky.

	Distance from feet to circle (cm)	Diameter of circle (cm)	Work	Angular size (°)
Fist				
Thumb				
pinky				

Name: ________________________________Lab Day & Time: ____________________________

Now you can use your hand to measure the angular size of other objects! For example, if you see an object that is completely covered with one fist and a thumb to cross the object, then its angular size is the angular size of your fist plus the angular size of your thumb, etc. For the following part 1-4, use your hands and your hand's angular size from above.

1. Stand 1m away from the moon poster on the North West corner of the classroom. From where you are standing, using your hands, what is the angular size of the moon?

2. Stand at the 3-meter mark. What is the angular size of the moon?

3. Stand at the 6-meter mark. What is the angular size of the moon?

4. As your distance from the Moon increased, what happened to the angular size of the Moon?

5. Hold the page of circles at arm's length. Measure the distance from the paper to your eye in cm.

_____________________________ cm

6. Calculate the diameter of the circle that has the same angular size as the Moon (Question2, P6).

$$Diameter = Distance\ from\ Paper\ to\ eye \times \frac{Angular\ size\ of\ the\ Moon}{57.3}$$

Diameter = ____________________________

7. Find the circle that best matches the diameter you just calculated, and draw a square around it.
8. Our nearby galaxy, Andromeda galaxy is moving towards us. What will happen to its angular size in the sky in the future?

____

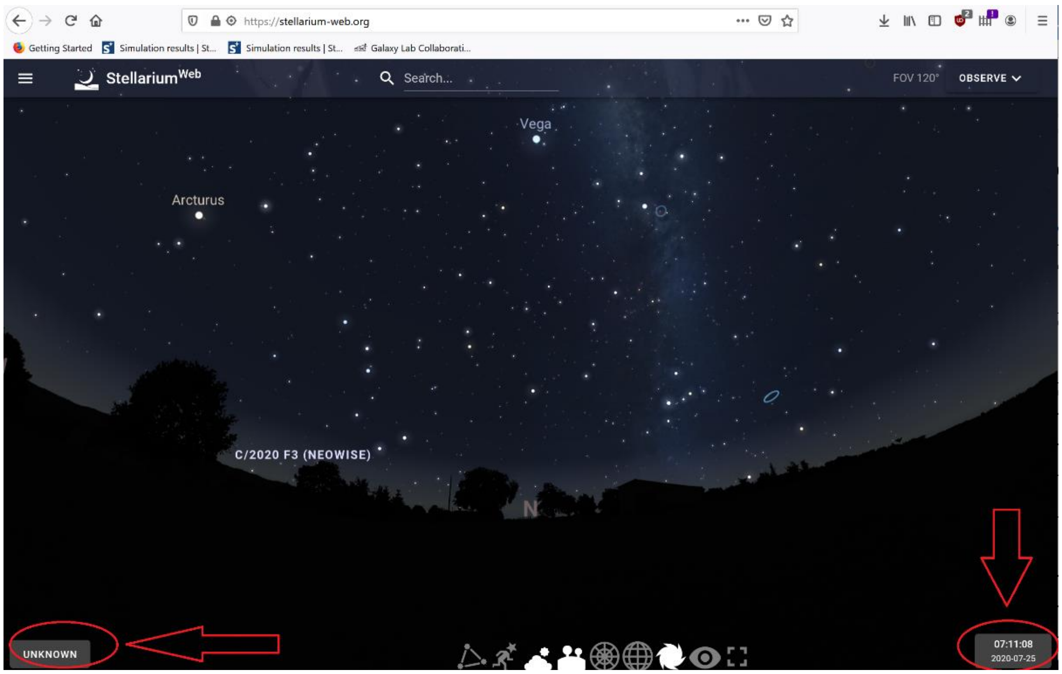
Name ____

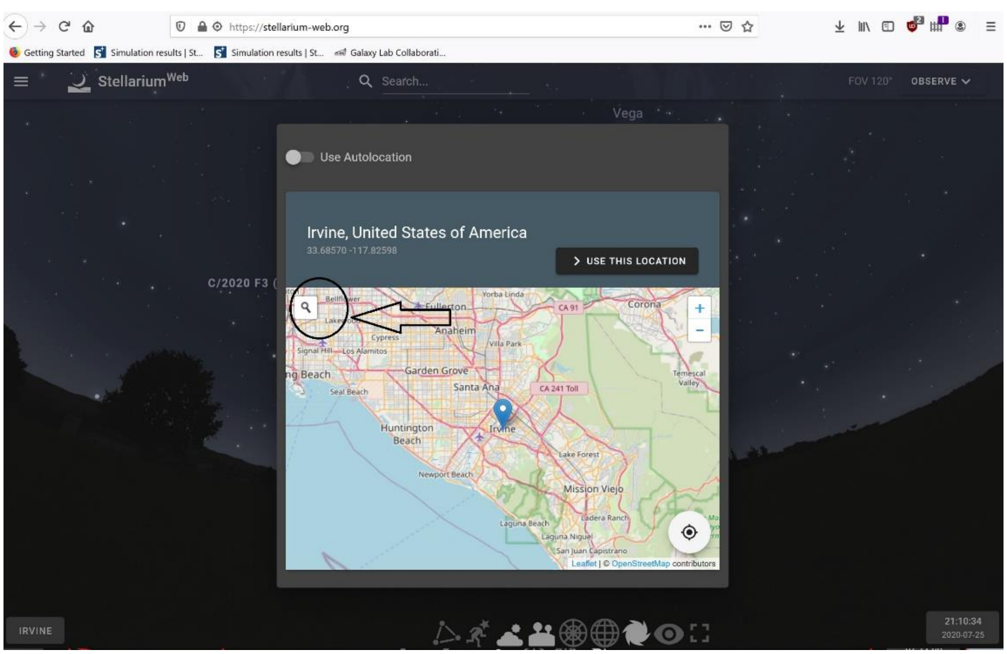
Sky Motions and Coordinates

Go to https://stellarium-web.org/.

Topocentric Coordinate System

Once you enter the website, you should see a landscape. On the bottom left of the screen, you can set your location. Click the button, and a map will pop up. Click the search icon, and search for Los Angeles, CA. On the bottom right of the screen, you can find the date and time. Click on it, and click the clock icon to set the date and time to the current date and time. Pause the time.





Name ____

1. If it is daytime, write down your current date, year, and time. If you are doing this lab at nighttime, change the time to 8AM.

YYYY/MM/DD: time (AM/PM)

____

Drag the screen around, and find the Sun. Double click on the Sun to get information about it.

2. What is the altitude and azimuth of the Sun currently?

Altitude _____________ Azimuth: _________________

3. Predict: From which direction (NSEW) did the Sun rise today? Towards which direction will the Sun set today?

Rise:__________________ Set:____________________

4. On the bottom of the landscape, you should see several icons. Click on the icon that says "Azimuthal Grid". A grid that shows altitude and azimuth will show on the sky. Take some time to understand the coordinate of the grid. Drag The screen around to make sure you understand the number on the grid.

Once you are confident, click on the time again. Click on the up and down arrow of the hour to move the Sun to sunrise. Then, move the hours forward to make the Sun rise then set. Keep your eye on the altitude and azimuth of the Sun. How did the altitude and azimuth change? Did it increase? Decrease?

On the bottom of the screen, click on the icon that says "atmosphere". This will allow you to see all the objects throughout the day. Find the Moon. You can click on the hour backwards and forward until you see the Moon. Or, you can search for the Moon using the search function on the top of the screen.

5. Describe how the Moon's altitude and azimuth change. Did it follow the same trend as the sun or was it different? Explain.

6. What do you conclude about the altitude and azimuth of all the objects in the sky?

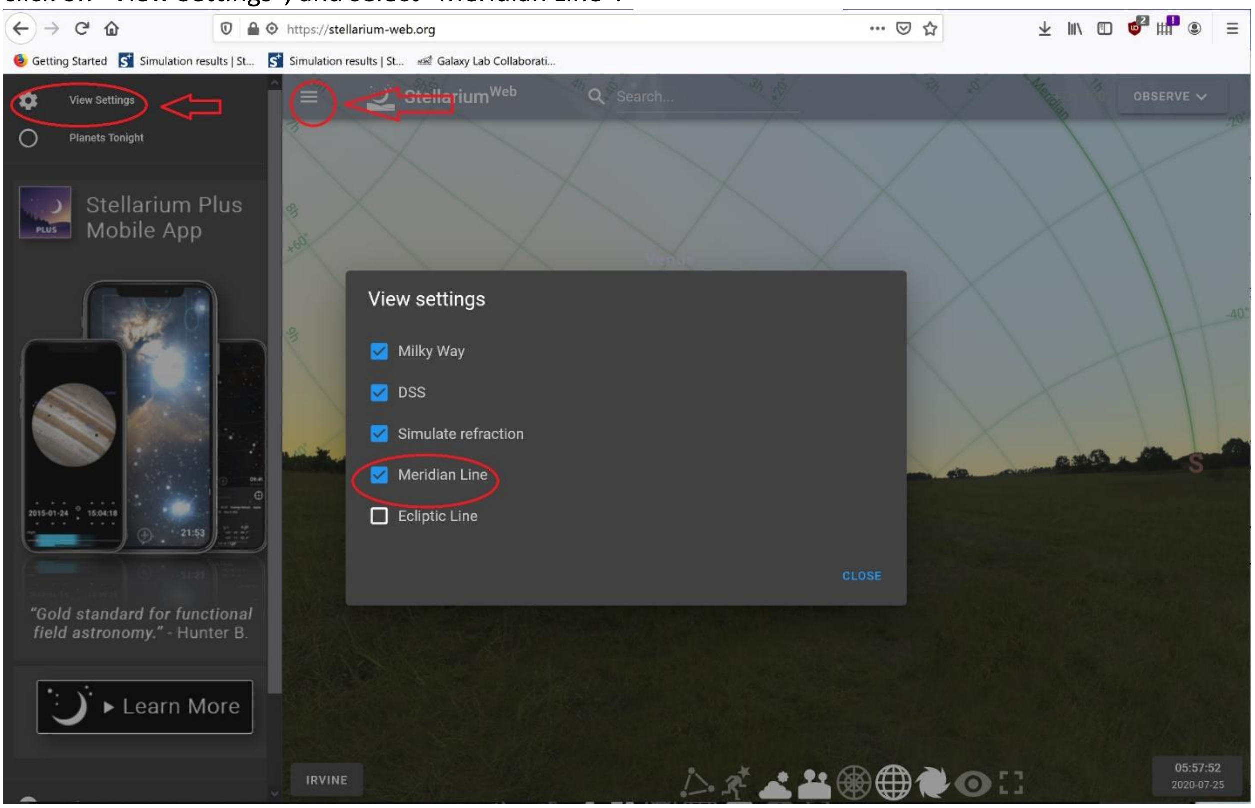
Name ____

Equatorial Coordinate System

1. Making sure that you keep the same date as above, change the time to the time of Sunrise. To do this, bring to Sun to horizon in the morning. What is the local time? ___________________
2. Double click on the Sun to get information. What is right ascension and declination of the sun?

Right ascension ________________ declination ________________________

Click on the Azimuthal Grid to turn it off. Click on "Equatorial Grid" that is next to it. This will show the grid of altitude and azimuth.
If you have closed the options that shows on the left, click on the three lines on the upper left. Then click on "View Settings", and select "Meridian Line".



Again, spend some times to understand the coordinates and the numbers. Make sure that you understand which lines are Right Ascension and Declination. Make sure you understand how the units work. Once you are confident, read the approximate Right Ascension of the meridian.

3. Read RA of meridian. ________________________

4. Find the difference in the RA of the Sun, and RA of the meridian. _________________

Look at the current time. Remember that transit is when the Sun crosses the meridian, which occurs at 12PM (If you are in daylight savings time, it will be 1PM).

Name ____

5. Imagine you don't have a clock, but you can determine the RA of the Sun and meridian. From what you have calculated in the previous questions, describe how you can use the RA of the meridian and the Sun to predict when the Sun will transit.

---

6. Let's go forward in time to see the sun transit. Note the time ________________.
7. Open the time option. Click and hold the minute arrows to make it go forward and backward in time. Don't click, make sure you click and hold. Observe the motion of the sun from sunrise to sunset. Did RA and Dec change? Explain.

---

8. Find the Moon again for the day you are doing the lab. Move the Moon to its rising position. Double click on the Moon to find information about it.

Local time at its rising position: ________________

Right ascension ________________ declination ________________________

9. Read RA of meridian. _____________ What is the difference in RA ____________

10. Let's go forward in time to see the Moon transit. Note the time ________________

Describe RA and Dec of this object throughout the day. Did it follow the same trend as the sun? In what way were they different or the same? Explain.

---

11. Move the Sun back to transit. Find Venus. What is the right ascension and declination of Venus?

Right ascension ________________ declination ________________________

How do RA compare to the sun's RA? (circle one) Smaller larger

Which direction is Venus compare to the sun? east west

12. Find Mercury. During the Sun's transit, what is the right ascension and declination of Mercury?

Right ascension ________________ declination ________________________

Name ____

How do RA compare to the sun's RA? (circle one) Smaller larger

Which direction is Mercury compare to the sun? east west

13. Let's say the Sun is still at transit. If an object is east of the sun, will RA be larger or smaller than that of the sun? Explain

14. Sirius's RA is about 6hours 45 minutes. If the meridian aligns with right ascension 4hours and 45 minutes now:

Which direction is Sirius? East or west of the meridian. ____________ Explain your answer:

15. When will / did Sirius transit? ____________________ from now/ago.

How did you determine the transit time?

16. Pleiades is located ~3hours 45 minutes. If the meridian aligns with right ascension 4hours and 45 minutes now:

Which direction is Pleiades? East or west of the meridian. ____________ Explain your answer:

17. When will / did Pleiades transit? ___________________ from now/ago

How did you determine the transit time?

Name ____

Coordinates

Topocentric Coordinate System

Fill in the following blanks.

1. The point directly overhead for an observer is called the ________________________.

2. Ground level for an observer is called the __________________________.

3. The altitude for a star at the ground-level is ___________________

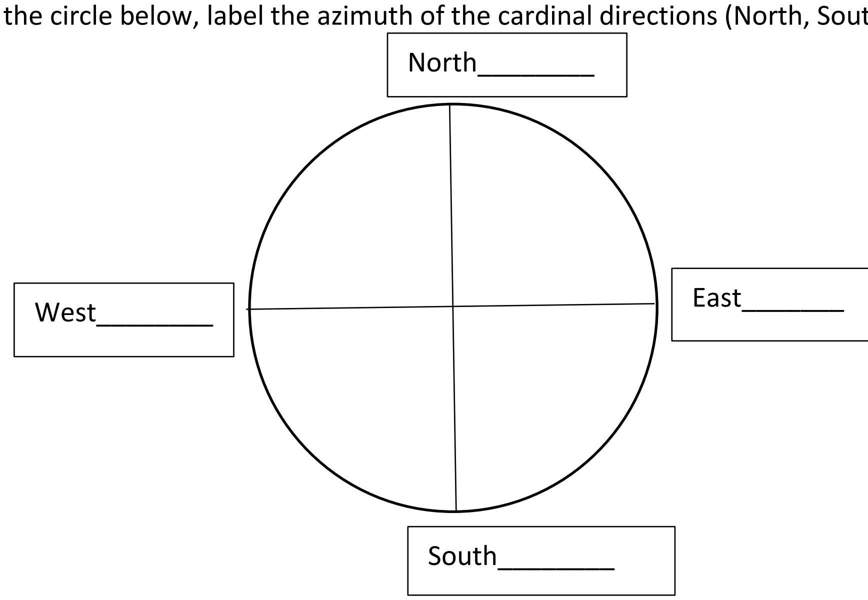
4. The altitude for a star directly overhead is ___________________

5. At the North Pole, what is the altitude of Polaris? What is the latitude of the North Pole?

____

6. The altitude of Polaris is always equal to the _____________________ of the observer.

7. If a star is on the horizon, what is its altitude? ____________________________
8. On the circle below, label the azimuth of the cardinal directions (North, South, East, and West).



Name ____

9. Use the attached star chart to complete the table below.

Star	Altitude	Azimuth
Deneb		
Aldhibain		
	65.5°	85°
Aldermin		
Mirfak		
	69.6°	86.5°
Eltanin		
	37°	72°
Mirach		
	62°	70°
Almach		
Vega		
	59°	329°
	58°	274°

10. If a star is before transit, will it be found more towards East or West?

____

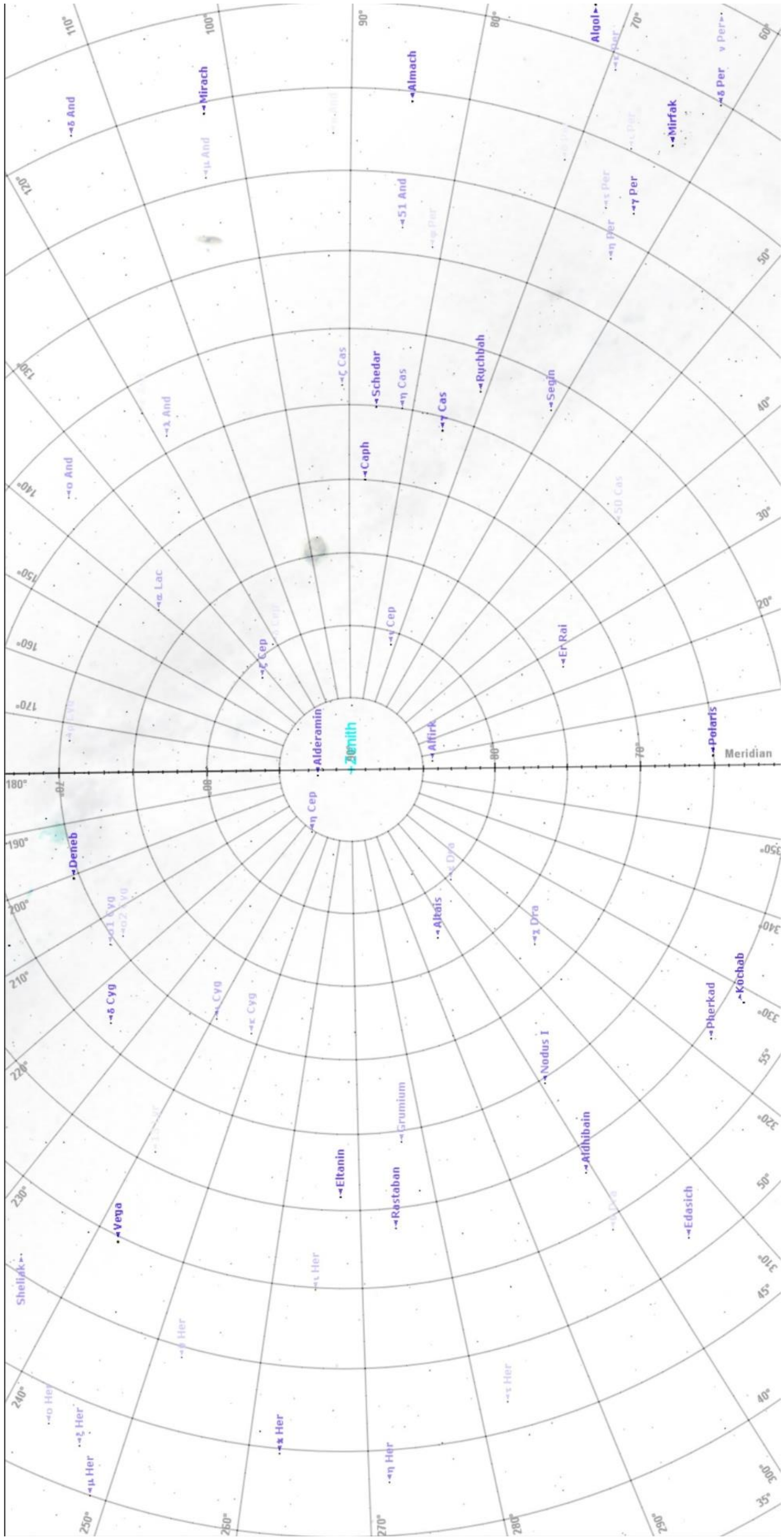
11. If a star is after transit will be found more towards East or West?

____

12. For each, star tell whether it is before or after transit, and whether it is found more towards the north or south. *Make sure you look at the azimuth numbers. The directions are mirrored in the skymap, but the numbers are correct.*

Star	Before/After Transit
Algol	
Eltanin	
Deneb	
Aldhibain	
Schedar	
Kochab	
Vega	

Name ____



Meridian
Zenith
Polaris
Kochab
Pherkad
Alderamin
Alfirk
Deneb
Vega
Eltanin
Rastaban
Grumium
Aldhibain
Edasich
Nodus I
Altais
Caph
Schedar
Ruchbah
Segin
Almach
Mirach
Mirfak
Algol
Sheliak
Er Rai

Name ____

Celestial sphere

Find a blue opaque celestial sphere (not the clear sphere with the Earth inside). Remove it from the stand. To familiarize yourself with it, locate the following references on the celestial sphere: Celestial equator, ecliptic, North & south celestial poles, equinoxes & solstices, right ascension& declination measurements.

1. What is a constellation? What is a zodiac?

2. When is your birthday: ____________________________

3. On your birthday, which constellation was the sun in?______________________________
4. Is this your zodiac sign? Yes / No
5. The sun is in Gemini on July 4th. Will you be able to see Gemini in the sky at midnight on July 4th? Explain.

6. Count the # of constellations on the ecliptic. How many zodiacs are there? __________

Which constellation is not commonly used in modern astrology? Look up that constellation in your little blue book (Field Guide to the Night Sky); write a few things about this neglected constellation!

7. Use the celestial sphere and fill the blanks. 8

Constellation	Star	Right Ascension	Declination
Orion	Betelgeuse		
Canis Major	Sirius		
Canis Minor	Procyon		
		20h 41m	$+45^0$ 16’
		18h 37m	$+38^0$ 47’
		19h 51m	$+8^0$ 52’
Ursa Major	Mizar+Alcor		
		16h 25m	-26^0 26’

Name ____

Planisphere

1. What is the date? What is your latitude today? What is the latitude ranged printed on the planisphere?

Take a moment to read the instruction on the back of Planisphere.

2. Write down one dominant constellation you should see in the direction indicated below, today 9pm.

Western Horizon

Northern Horizon?

Eastern Horizon?

Near your zenith?

Southern Horizon?

---

3. Which triangle in the sky is visible today at 9PM? summer triangle/winter triangle
4. In which direction do you see the triangle (NSWE)?

Direction: _______________________

5. Rotate the wheel so the triangle starts to set. Find the time when the first of the three stars sets. Repeat to make the star rise. What time did it rise and set today?

Name of the star: _______________________ time it sets: ________________AM/PM

Time it rises: ________________________________

6. What is its declination and right ascension?

Right ascension: __________________ Declination: ___________________

Name ____

7. On which day of the year will this star rise at 9pm? _________________________

8. On which day will it cross the meridian at 9pm? _______________________

9. On which day will this star set at 9PM? _____________________________

10. This star is visible over _____ month(s) out of the year.

11. Find a bright star that crosses the meridian at 9PM in about 6 months from your answer to question 8. What is its right ascension and declination?

Name: ___________________

RA: __________________, DEC: ___________________

12. Follow the same procedure above to find how many months this star is visible at 9 PM.

____

13. Find Cepheus. Follow the procedure above it to find how many months this constellation is visible at 9PM. ___ months
14. What do you call a star like Cepheus? _____________________
15. Find Orion. Place it near the meridian. The center of Orion is ~ 5h30m. The face of Taurus is ~ 4h30m. If you are observing Orion, in which direction would you find Taurus: West or east?
16. Find Vega (in Lyra). Place it near the meridian. Vega is at ~ 18h30m. Deneb (another star of the Summer Triangle) is ~ 20h30m. If you are observing Vega at the meridian, in which direction do you find Deneb: West or East?

17. Find M31. What kind of object is it? ________________________________

18. in what constellation is it located? _____________________________

19. What is its right ascension and declination?

RA:___________________ DEC:_____________________

20. In what month can you see this object at 9pm? Circle all applies. If you can see at least 75% of the constellation, you can call it as it's visible.

January February March April May June July August September October November December

Name ____

21. Find M13. What kind of object is it? _____________________________

22. in what constellation is it located? __________________________

23. What is its right ascension and declination?

RA:_________________ DEC:___________________

24. In what month can you see this object (at 9pm)? Circle all applies

January February March April May June July August September October November December

25. Which constellations were visible near the zenith at 9PM on your birthday? List one constellation.

____

26. What is your zodiac sign (circle in table below)? In which months is this constellation visible at 9pm? 2pts

Aquarius	Pisces	Aries	Taurus	GEmini	Cancer
1/20-2/18	2/18-3/20	3/21-4/19	4/20-5/20	5/21-6/20	6/21-7/22
Leo	Virgo	Libra	Scorpio	Sagittarius	Capricorn
7/23-8/22	8/23-9/22	9/23-10/22	10/23-11/21	11/22-12/21	12/22-1/19

January February March April May June July August September October November December

Name ____

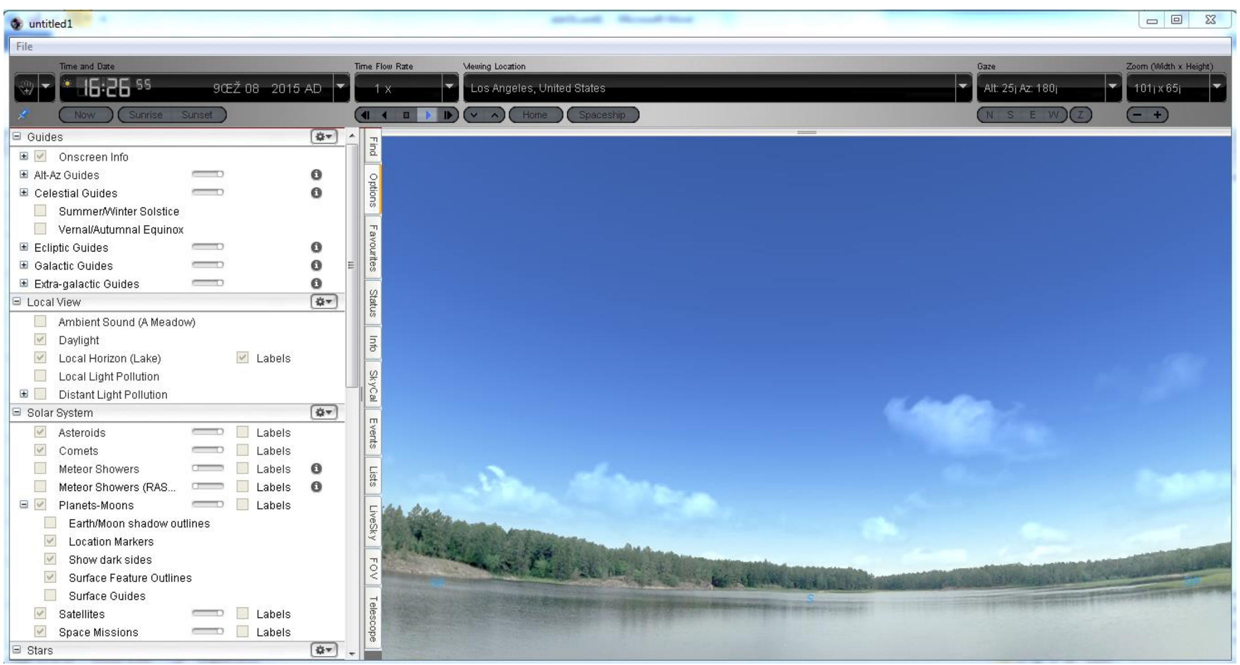
Starry night

Purpose of today's lab is to become familiar with the Starry night program. Starry night program is computer simulation of celestial sphere, which can be used to investigate the celestial objects for viewers from different places.

1. Open the Starry Night program

Open Starry Night college by going to: "Start" -> "All Programs" -> Starry Night college 6.-> Open.

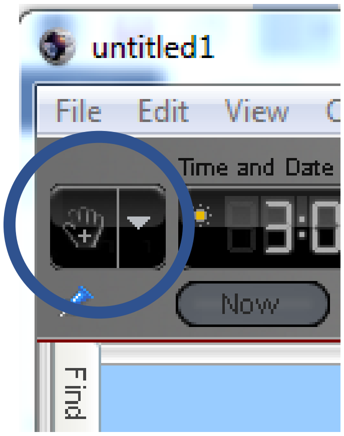
2. If "home location" is not set to Los Angeles, go to "options" from the top menu and select "viewing location". This opens the "viewing location" sub window. You can be at surface of Earth or other planets, center of a planet, or stationary position. For today's lab, you will stay on the surface of the earth.
   In this window, you can select location by typing in the location, select the location on a map, Latitude and longitude or by zip code. When you select your location by location name, your latitude and longitude is displayed. Select "Los Angeles". Tap the space bar to instantly move to the new location.
3. Get familiar with the program!
   a. Use the hand icon to move your views around. Put the hand anywhere in the sky or horizon, click and drag to move your view. Can you go all the way around?
   b. Click on "Options" tab on the left hand side. Expand "Local view", check on "Local Horizon". Double click on the word "Local Horizon" Horizon style window will open. Click on " Flat horizon" -> OK to close the window. Click on the "options" tab again to close the tab.

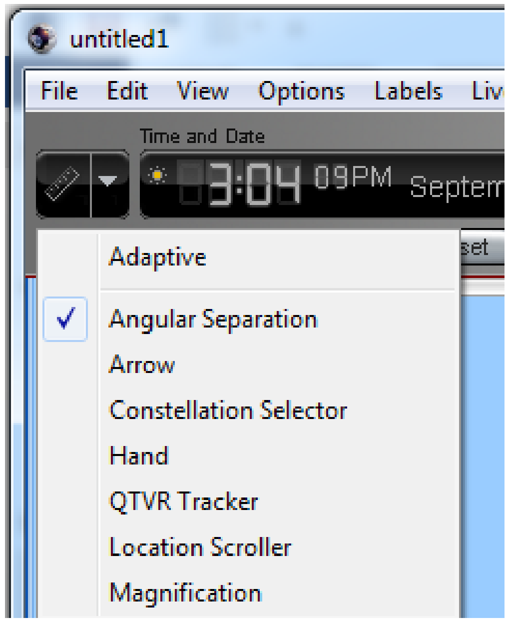


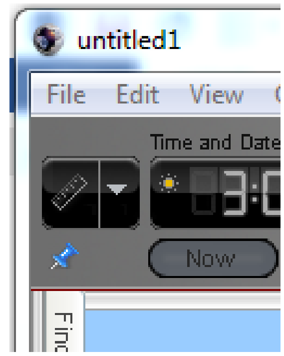
   c. If not set automatically, set the time to "now" by clicking the dropdown menu of the date and time. Now we will measure the altitude of the Sun. At the current time, in which direction do you expect to see the Sun? Drag the screen around and use the directions (NSEW) as a guide to find the sun. Alternatively, you can click the "find" tab on the left-hand side. If you see the "sun" already, double click on it. Otherwise in the search box type in "Sun" and double click on it when the Sun pops up. To measure the

Name ____

altitude, use the top left dropdown measure and choose “Angular separation”. (The top left corner icon will change from “hand” to “ruler” icon.) Click and drag between the sun and the horizon, and read the angular separation. This will be the altitude. Also, if you hover your curser above the Sun, the current altitude will pop up.







Date & Time ______________________________

Altitude: ______________________ Azimuth: _______________________

d. Display: use the “Option” tab to choose what you would like to display. For now, leave the display as it is.
e. Now we will change locations. Use the dropdown menu “Options” -> “viewing location” to change location. Go to Stirling. Tap the space bar to go instantly. In which country is Stirling located (NOT United States!)? What is the longitude and latitude?

Country: ______________________________

Longitude: __________________ Latitude: _______________

f. Now go back to Los Angeles. Display Ursa Minor to locate the North Star.- Click on “find” tab to the left, type in “Ursa Minor”. Click on the box next to the name to display the image of the constellation (Make sure you click on the box for the constellation, not the galaxy). Click the “find” tab again to close the tab. Since it is currently daytime, in order to see Polaris, the North Star, we must turn off the sunlight. Click on the “view” tab on the top menu bar. Select “Hide daylight”. Polaris is the brightest star in Ursa

Name ____

Minor, located at the tip of the little bear. Is the North Star (Polaris) visible from Los Angeles, under normal circumstances? YES NO

g. What is the sunrise and sunset time today from this location? Underneath the day and time display, click the "sunrise" and "sunset" buttons to see the time.

Sunrise: _____________________ Sunset: __________________

h. Use the dropdown menu "Options" -> "viewing location" to change location. Go to Melbourne. In which country is Melbourne (NOT United States!)?

____

i. What is the longitude and latitude?

Long_____________________ Lat__________________

j. Use step f to find Ursa Minor from Melbourne. Is the North Star (Polaris) visible from this location? Does this make sense? Explain

____

k. What is the sunrise and sunset time today?

Sunrise: _____________________ Sunset: __________________

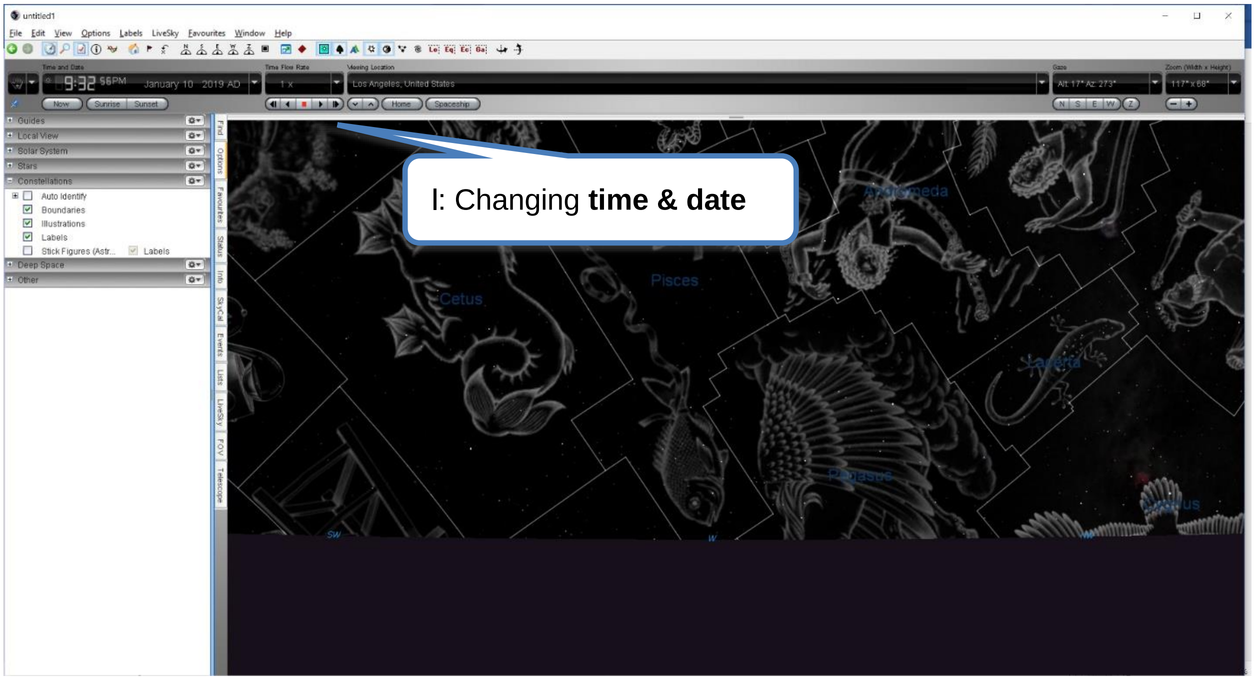
What are the two conditions required for you to observe the North Star?

____

How to change time & date

l. Go back to Los Angeles. At the bottom right of the date and time display, you should see a playback control panel with "play, stop, backwards, forwards" buttons. Click on the black square button to stop the flow of time. Click on the "options" tab to the left, then under "constellations", check the boxes for "Boundaries, illustrations and labels"

Name ____



m. Set time to 9pm tonight. Look toward the Western horizon by clicking on the "W" button at the top right of the screen. Alternatively, you can drag the screen around until you are looking at the western horizon. Should you see the stars / constellations to be rising or setting?

____

n. Which constellation is about to rise or set? For this purpose, select a constellation that is 100% visible (not touching the horizon).

____

o. Set the time step to 1 hour by using the drop-down menu on the time flow rate. Go forward in time, one step at a time by clicking the forward button. At what time did the next constellation (the one after your answer in part n) rise/set? What is the name of that constellation?

____

p. Set the time back to 9pm. Look towards the Zenith by clicking "z". Write two constellations you see toward Zenith. Write two constellations you see *near the horizon* towards North, South, East, and West.

Zenith____

West ____

East ____

Name ____

North ____

South ____

Field of View

We can zoom in and out by changing the field of view. Turn the constellations off because the view is too busy.

Find object: Mizar (use "find" tab). What is the apparent magnitude of Mizar? Hover over Mizar to get the information. _______________

Use the +/- button at the top right corner to zoom in. As you zoom in, at around 86^0, you should notice that the Mizar has a companion star. Zoom in to about 10^0. Hover your curser over the companion star and find some information about it:

Name:___________, Apparent Magnitude ______, In constellation: _____________,

Use the "Angular Separation" to measure the angular distance between Mizar and this star _________

The smaller the magnitude number, the brighter the star. Is this star brighter than Mizar? __________

Set the time back to the current time. Find the Sun, right click to center. Zoom in to ~5°, past the glare. what is the angular diameter?

____

Find the Moon right click to center. Zoom in to ~5°. what is the angular diameter? Measure the size of the faint outline, so that you measure the size of the whole Moon.

____

Celestial motion

Stop the time flow, make sure that your horizon is flat.

Go to the North Pole. To do this, go to Latitude 90N by "Viewing Location" drop down menu. Select "other", and choose "Latitude / Longitude" tab. Enter 90N. You do not need to change your longitude. This will take you to the North Pole.

Why do you not need to change your longitude? Why does it not matter?

____

Click on the "S" at top right corner to face towards "South" direction.

Under "Option" tab on the left:

Guides: Under Celestial Guides, turn on Poles and Circumpolar Region but leave everything else off.

Local View: daylight: off, local horizon: on, other options: off.

Solar system: all options off

Stars: Stars, on, Milky Way: off

Constellations: Boundaries: on, Labels: on, Stick figures: on, other options off.

Name ____

Next to the time display, open the drop-down menu for the time flow rate. Select minutes and click on the number to type in 1. Click on the play button to start the flow of time.

Using the direction button under “Gaze” to face towards west. Observe the motion of the stars. Use arrows to draw the motion of the stars. For example, draw ↗ if the stars are moving towards the upper right.

____

Gaze towards East: Use arrows to describe how the stars appear to move.

____

Do all the stars seem to move parallel to the horizon, at a large angle to the horizon or perpendicular to the horizon?

____

Face towards zenith. Describe the motion of the sky. Is the sky motion clockwise or counterclockwise?

____

Zoom out as far as possible. What is the width and height of your zoom?

_____________ X ________________

Find North Star: what is the altitude of the North star? __________________________________

The red line indicates the circumpolar region. Stars in this region remain visible above the horizon at all times at that specified location on the earth’s surface. What is the % of the circumpolar zone with respect to the whole celestial sphere? You may have to turn off the horizon the see this.

____

Now go to Los Angeles: Change the location to Los Angeles. What is the latitude? ___________

Face towards west. Click on the play button to start the flow of time. Use arrows to describe how the stars move.

____

Gaze towards East: Use arrows to describe how the stars appear to be moving.

____

Do all the stars seem to move parallel to the horizon, at a large angle to the horizon or perpendicular to the horizon?

____

Name ____

Find North Star: what is the altitude of the North Star? ______________

Quito, Ecuador: Change the location to Quito. What is the latitude? ____________
Using the direction button under "Gaze" to face towards west. Click on the play button to start the flow of time. Use arrows to describe how the stars move.

____

Gaze towards East: Use arrows to describe how the stars move.

____

Do all the stars seem to move parallel to the horizon, at a large angle (diagonal) to the horizon or perpendicular to the horizon?

____

Find North Star: what is the altitude of the North Star? __________

What is the % of the circumpolar zone with respect to the whole celestial sphere? _______________

Now go to the South Pole: Change the latitude to 90S.
Using the direction button under "Gaze" to face towards west. Click on the play button to start the flow of time. Use arrows to describe how the stars move.

____

Gaze towards East: Use arrows to describe how the stars move.

____

Do all the stars seem to move parallel to the horizon, at a large angle (diagonal) to the horizon or perpendicular to the horizon?

____

Face towards zenith. Describe the motion of the sky. Is the sky motion clockwise or counter-clockwise?

____

in which constellation is the south celestial pole located? _________________________________

What is the % of the circumpolar zone with respect to the whole celestial sphere? _______________
Compare the motion of the sky at the 4 different locations you investigated above. Imagine traveling from the South Pole to the North Pole, and looking at how stars rise and set at each location. As you move from low latitude to high latitude, did the angle change? How? Did you notice and trend or pattern? Explain:

Name ____

Evaluate the altitude of the North Star at the first 3 different locations. Do you see any patterns? What relationship do you find between latitude and the altitude of the North Star?

Location	Latitude	Altitude of the North Star
North Pole		
Los Angeles		
Quito		

For the following questions, answer Equator, North Pole, South Pole, or Mid-Latitude.

Where on earth do you need to be to see all the stars over the course of a year? __________________

If all the visible stars are circumpolar stars, you must be at: ____________________________________

If you wish to see the North Celestial Pole coincide with your zenith, you must be at: ________________

If you wish to see the celestial equator coincide with your zenith, you must be at: ___________________

Navigating the celestial sphere

1. Return to LA, today. If not already, make sure the search box is empty and click enter. On the left tab under "Options" -> "Solar System", turn back on "Planets and moons".
2. On the left tab under "find", check the box on Saturn (don't search). Expand the Saturn menu and click on Dione, Pan, and Mimas (under "Smaller Moons"). Double click on the word "Saturn" to center.
3. Zoom in to about 1' x 0.5' (arcmin, not degree). Draw Saturn with its moon's locations, and label them.

Name ____

4. Right-click on Saturn, and check “centre”. Go forward in time by 1 minute. Which one of the selected moons is moving fastest?

____

5. Why is this moon moving faster than the other moons?

____

6. Zoom out to see in what constellation Saturn is located today.

____

7. Go to top menu “options”-> “stars” -> “stars”. You will see the star options sub window. Click on “Labels” and change “show” to “Magnitude”. Remember, smaller the number, brighter the star. Right-click on the star, and choose “show info”. What is the name of the brightest star in this constellation? What is the spectral class of this star?

Name: ____________________________________ Spectra Class: ___________________________

8. What color is the star? _________________________ see page 26 of your little blue book.
9. Is this star hotter than the sun or cooler? Explain your reasoning.

____

Name ____

10. Deep sky objects: Uncheck the star labels. Zoom in to fill this constellation on your screen. Under Options tab on the left-hand side, look at Deep space. Click on labels for "Bright NGC objects" and "Messier objects". Uncheck everything else. You should see several names pop up. Choose two, and zoom in. You will have to zoom in a lot. Write down their names and sketch them in the boxes. Hover your curser on the object, and write down what type of object it is. If no picture is available in your constellation, you can choose a deep sky object from nearby constellations. If you do so, be sure to write down which constellation they are in.

Name: ______________________ Name: ______________________,

Object Type: ____________________________ Object Type: __________________________

11. When is this constellation (use the constellation from part 6) visible from Los Angeles? Turn the horizon back on. Right click with in the constellation to "center / lock" on the constellation. Set time to January-15 for this year at 9pm. Set the time control step to 30 days. If the constellation is above the horizon, it is visible during that month. Use the method you used above (in section where you have displayed only Ursa Minor to find the North Star), to show the illustration for only this constellation. Use the "step forward" button (not the play button!) to move time forward. Circle all the months when the constellation (more than 50% of the constellation) is visible at 9pm. Or circle never visible.

Never visible January February March April May June July August September October November December

When is this constellation visible from Sydney Australia at 9pm?

Never visible January February March April May June July August September October November December

When is the constellation Ursa Minor visible from Los Angeles at 9pm?

Never visible January February March April May June July August September October November December

*Constellations or stars that are always visible are called circumpolar constellations!

When is the constellation Ursa Minor visible from Sydney, Australia at 9pm?

Never visible January February March April May June July August September October November December

Name ____

If a constellation is near the celestial equator, do you see the constellation at different time of the year or same time of the year from Los Angeles and Sydney Australia? Will the constellation be in the same or different direction? Explain your answer:

If a constellation is near North Celestial pole, do you see the constellation at different time of the year or same time of the year from Los Angeles and Sydney Australia, if at all? Explain your answer:

____

Temperature

In astronomy we use the Kelvin as unit of temperature (1K is the same incremental value as 1°C). The Kelvin scale is named after British physicist Lord Kelvin. In the Kelvin scale, water boils at 373K and freezes at 273K. To convert:

Fahrenheit and Kelvin: $TK = \frac{5}{9} \times (TF - 32) + 273$ or $TF = \frac{9}{5} \times (TK - 273) + 32$

Example: let's say it is 75°F in this room. TK = (5/9)*(75– 32) + 273 = 297K

Use this to fill in the blanks. Show your work.

Water boiling temperature	373K	°F
Surface temperature of Titan	K	-290°F
Surface temperature of Mercury at its hottest	K	750°F
Surface temperature of the Sun	5800K	°F

Name____

Moon & Eclipse

The Moon and Eclipses: Be sure to write your name & answer all short answer questions in complete sentences.

Phases of the Moon

One of the most common occurrences in astronomy that we are all familiar with is the change in phase of the Moon from night to night. Most of us see this on regular basis, but have you ever explained why it happens? The goal of today's lab is for you to gain a better understanding of this lunar phenomenon.

You will need a lab partner to set up a Sun-Moon system and investigate the phases of the Moon. A light bulb at the back of the classroom will represent the Sun. The diagram and classroom activity set up assume you are looking at the Earth-Sun-Moon system from high above Earth's north pole.

In which direction would Earth be spinning? Clockwise counter clockwise

In which direction would the Moon orbit around the Earth? Clockwise counter clockwise

1. Get a small Styrofoam ball which will represent the moon. One of you will be the "moon" and hold the styrofoam ball and the other will sit in a chair and be the "earth." You will switch places later.
2. From Earth, the time of the day you see the Sun at the highest position in the sky is

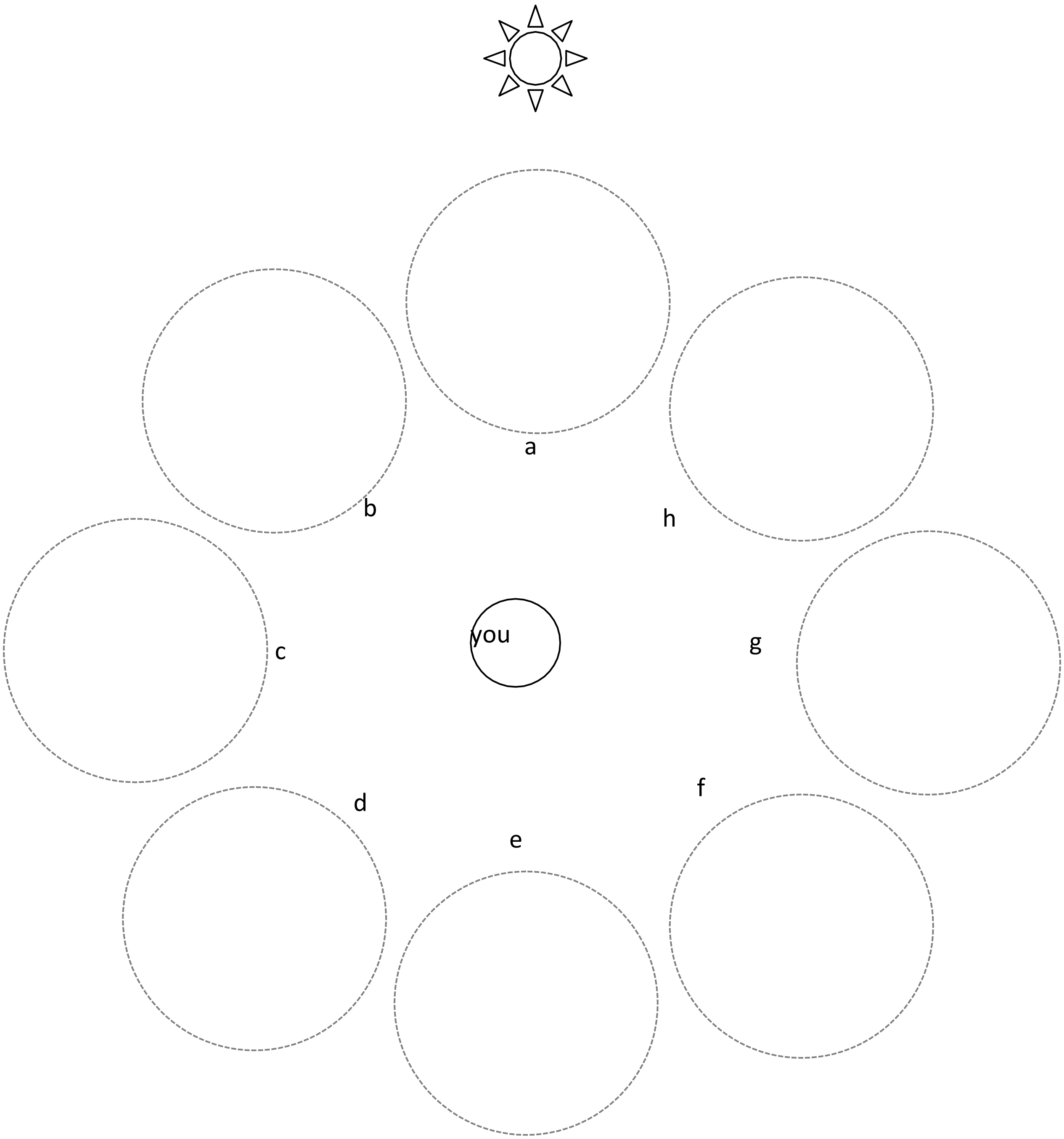
____

3. If an object is to your right-hand side, is it rising or setting? ______________________________

If an object is to your left-hand side, is it rising or setting?______________________________ Spin around to find out.

4. Sketch what phase of the moon you see at each location. When you've seen each "phase," switch places with your partner.
5. Label your sketch with the appropriate phase name: New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Third Quarter, Waning Crescent.

Name____



a		b		c		d	
e		f		g		h	

Name_______________________________________

Phases of the moon simulation

Open Lunar phase simulator applet. Open Class Action. From “All Modules”, go to “Lunar Cycles”. From the bottom menu under “Animations” -> “Lunar Phase Simulator (NAAP)”

1. Main part of the display shows Earth Moon system observed from above the North Pole. In which direction will the moon orbit the earth? Clock wise or counter clock wise?

____

2. In which direction is the earth rotate? Clock wise or counter clock wise?

____

3. Click on the “start” to observe the phase changes. Pay attention to all 3 parts of the simulator. This will help you understand why we see different phases of the moon. How long is the lunar phase cycle?

____

4. Check “show lunar landmark and run the animation for a complete cycle. Does the moon rotate on its own axis? If so, what is its rotational period?

____

When observing the moon one thing we might like to know in advance is when it is visible, such as what time it rises, sets, and crosses the meridian (or transits). The applet can help find these times.

For example, we will find the meridian crossing (transit) time for a new moon. On the main simulator display, move the moon to the “new Moon” position. Then click on the observer to drag him/her around. On the horizon diagram, you can see the Moon in various positions in the sky as you rotate the observer in the main display. It will help to change the perspective of the horizon diagram to observe the Moon as it is exactly rising, setting, or in transit. Rotate the earth in the main display so that you see the Moon in transit in the horizon diagram. For the new moon phase, note that the transit time of the new moon is 12:00 PM.

5. Complete the rest of the table.

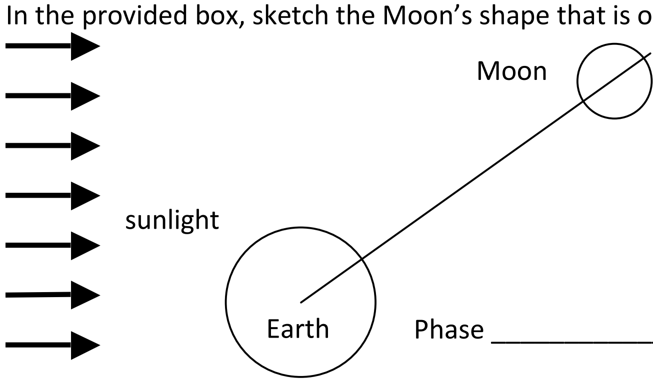
Name____

Illuminated part (+/-2%)	Time since new moon.	Phase	Rising time	Transit time	Setting time
0% illuminated	0d,0h	New moon		12:00pm	
		Waxing crescent			
Right 50%					
		Waxing gibbous			
100%					
Left 85%					
Left 50%					
			3:00am		

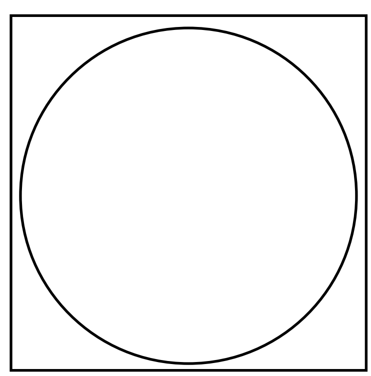
6. Discuss the patterns you discovered. How are the rise time, transit time, and setting time relate to one another? How do these times change from one phase to the next?

Visualizing Phases

We can determine the appearance of the moon based on the orientation of the moon and sun with a simple model. In the figure below, draw two lines. One line will be perpendicular to the direction of sunlight. This line splits the moon into a dark side and a light side. Shade in the side that is in the dark. The second line will be perpendicular to the Earth-moon line. This line splits the moon into the part we can see from the Earth and the part that faces away from the Earth. Mark the region that is both visible from earth *and* illuminated by the sun. That region will be the phase of the moon we on earth see.
In the provided box, sketch the Moon's shape that is observed from Earth. Write the phase.

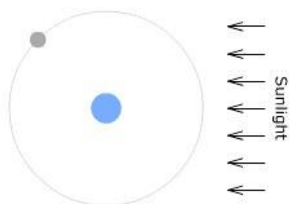
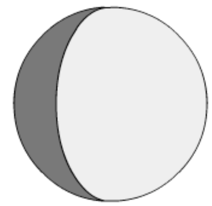
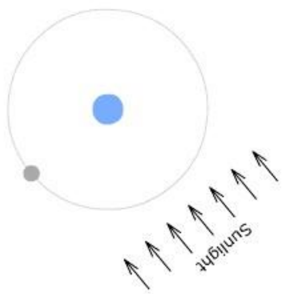
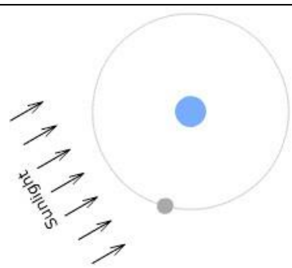
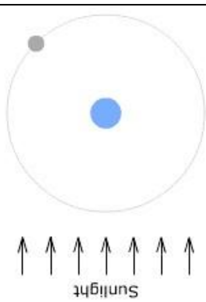
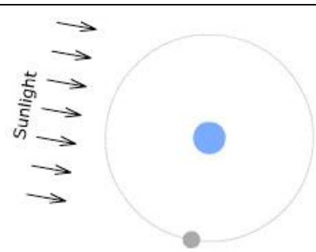


Phase ___________________________



Name_______________________________________

7. Each row on the following table shows diagram of the earth-moon system. For each diagram, find the moon's phase, its percent illumination and, finally, make a sketch of its general appearance.

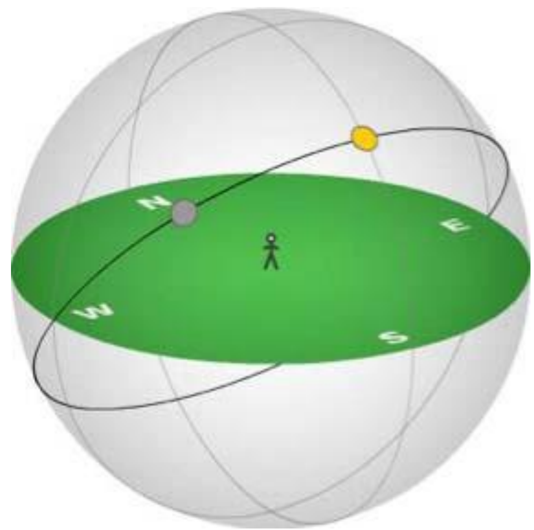
Moon Geometry	Phase	Percent Illumination	Sketch
	Waxing Gibbous	88%	
			
			
			
			

Name____

8. Complete the following table.

	Time	Phase	Location
A	Noon	First Quarter	
B	3PM	First Quarter	
C		First Quarter	Western Horizon
D	9PM	Waning Gibbous	
E	3AM		Southwest
F	12AM	Waxing Gibbous	
G		Waxing Crescent	Southeast

9. The figure to the right shows the moon and sun on a horizon diagram. Sun is in transit.



a. What is the moon phase and what is the time of day depicted?

____

b. What time did the moon reach its highest point in the sky?

____

c. In the figure, draw and label the moon's location 48 hours later.

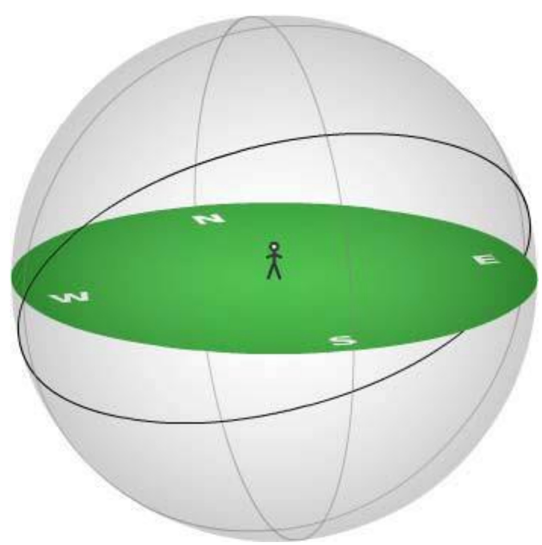
d. Will the moon be visible at noon in 14 days? Explain

____

____

____

10. Draw and label the full moon and the sun at 6:00 A.M. on the figure to the right.



If you faced the south, in which direction would you see:

The Sun: (circle the best description)

behind you in front of you

on your left-hand side on your right-hand side

The Moon:

behind you in front of you

on your left-hand side on your right-hand side

Name____

11. Suppose Sherlock Holmes is investigating a crime that took place at 3 AM, away from street lamps and any other artificial light sources. A witness claims he recognized the perpetrator in the light cast by a first quarter moon. Should the detective believe him? Explain your answer.

Starry Night Lab: Eclipses

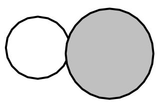
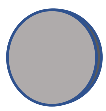
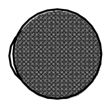
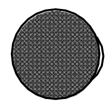
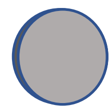
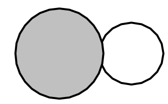
Eclipses are the phenomena during which the Sun or the Moon temporary becomes dark. Today we will investigate how the lunar and solar eclipse happens.

1. Add where the Moon would be during a solar eclipse in the diagram below (not to scale) and explain how and why solar eclipses occur.

2. Add where the Moon would be during a lunar eclipse in the diagram below and explain how and why the lunar eclipses occur.

Name____

Start Starry Night. Turn your local horizon and daylight off. Go to “events” tab on the left side. Under “event filters” at the bottom, check “Lunar and solar eclipse events”. Start date: today, end date 10 years from now (click on the end year and use up/down to change the year). If it asks about the number of events, click “search anyway”. Find a total lunar eclipse. Double click to go to that day. Right click on the moon to center on the moon. Go back/forward in time 1 minute at a time to find out what time each part of the event happens. Look carefully. The lighter shadow is called the penumbra, and the darker shadow is the umbra.

Eclipse begins (Penumbra)	Eclipse enters umbra	Totality begins	Totality ends	Eclipse exists umbra	Eclipse ends (penumbra)
					

Eclipse begins (Penumbra)	Eclipse enters umbra	Totality begins	Totality ends	Eclipse exists umbra	Eclipse ends (penumbra)

Date of the eclipse chosen______________________ Duration of totality:______________________

Find a total solar eclipse. Choose any total solar eclipse and right click. Click on “View event from alternate location”. Click on the “status” tab and note the location.

Location: Longitude & Latitude & country____
In the left box on the next page, sketch the total solar eclipse.
Zoom in/out to view the entire solar atmosphere. While you see the solar atmosphere is the duration of the totality.

Date of Eclipse	Eclipse begins	Totality begins	Totality ends	Eclipse ends	Duration of Totality

Which type of eclipse should have longer totality? Why?

Name____

Annular Eclipses

An annular eclipse is observed when the Moon does not completely cover the Sun. First, let's observe what an annular eclipse looks like. From the list of events in the previous section, choose an "Annular Solar Eclipse". Right click and select "View Event From Alternative Location". Sketch what you see in the right box below. Describe the differences.

Total Solar Eclipse	Annular Solar Eclipse

____

____

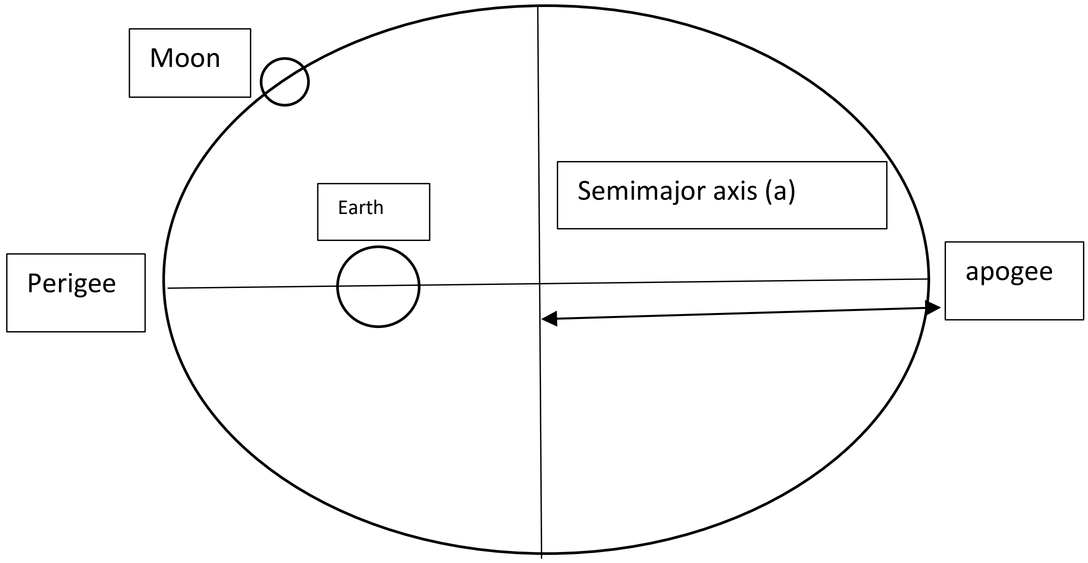
____

____

____

Name_______________________________________

To see why this happens, look at the diagram below. The Moon orbits around the Earth in an ellipse as shown (size, shape, and distance not to scale). “a” is the semimajor axis and e is the eccentricity of the Moon’s orbit. For an orbit around Earth, we use the term "perigee" to denote the point on the orbit closest to Earth and "apogee" to denote the point on the orbit farthest from Earth.



1. The equations $perigee = a \times (1 - e)$ and $apogee = a \times (1 + e)$ give the perigee and the apogee distances. For the Moon’s orbit, a = 0.3844×10^6 km and e = 0.0549. Calculate the distance from Earth to the Moon at perigee and at apogee. Show all work and units, and round your answer to the nearest km.

Moon at perigee: _____________________________

Moon at apogee: ______________________________

2. Recall that “angular size” is the apparent size of a distant object. The diameter of the Moon is 3,476 km. Use the equation:

$Angular\ size\ of\ Moon = \frac{Diameter\ of\ the\ Moon}{Distance\ to\ the\ Moon} \times 206{,}265$ to find the angular sizes of the Moon at perigee and apogee. This equation gives the answers in arcseconds. Show all work and units.

Angular size of the Moon at perigee: _____________________________

Angular size of the Moon at apogee: _____________________________

Name____

3. The diameter of the Sun is $1.392X10^6$ km and the distance is $1.496X10^8$ km. Use the equation from question 2 to find the angular size of the Sun in arcseconds. Show all work and units.

Angular size of the Sun: ____________________________________

Now let us summarize your calculations. Circle the best answer in the following sentences. "When the Moon is at perigee, the Moon appears larger/smaller than the Sun. When the Moon is at apogee, the Moon appears larger/smaller than the Sun."

4. Compare the angular sizes of the Moon at perigee and apogee to the angular size of the Sun. Complete the following sentence with "perigee" or "apogee".

For a total solar eclipse, the Moon must be near _______________ in its orbit around Earth.

For an annular solar eclipse, the Moon must be near ___________ in its orbit around Earth."

Name____

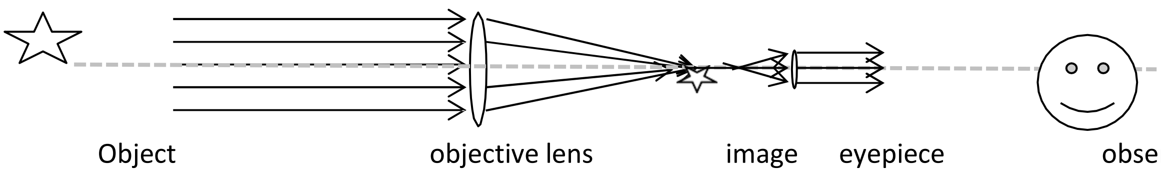
Telescope

Introduction

The telescope is one of Astronomy's most important instruments. Telescope has been in use for astronomical observing for about 400 years. Today, we will be learning about: Types of telescopes, How to use a telescope, Properties of telescope.

The basic telescope

Telescopes are made of combination of few lenses, usually an objective lens or mirror and an eyepiece, and sometimes secondary mirror. The objective lens gathers light from a light source. The eyepiece is used to magnify the image, so you can take a look at the details. Secondary mirror is used to change the direction that the light ray is traveling to place an eyepiece at a convenient location.



1. Light from far away object reaches us in "Parallel rays". The parallel ray that came into a telescope exits the telescope as a parallel ray. Why go through the trouble using a telescope to observe the light, if we are still looking at parallel rays? What is the advantage of observing using a telescope?

____

____

____

Properties of a telescope

Light Gathering power (light collecting)

Light Gathering power is a measure of the amount of light a telescope can collect. Since most stars are relatively faint, it is important that you gather much light as possible in order to see a good image. The *light gathering power is directly related to the surface area of the objective lens* that the telescope has. The surface area is:$A = \pi r^2$, where A is area, π is pi (3.1415, but leave it as π), and r is the radius of the lens (1/2 diameter). Greater light gathering poser will let you see dim objects!

2. Telescope A's objective lens diameter is 8 inches. Telescope B's diameter is 4 inches. Calculate the surface area of each telescope.

Name____

____

3. How much bigger is A's surface area compared to B's surface area? (remember the Number's lab) How many times more light-gathering power does telescope A has compared to the telescope B?

____

Magnification of a Telescope

The magnification of a magnifying glass indicates how many times larger an object appears through the magnifying glass. For a telescope, you find magnification by using the focal length of objective lens, and the focal length of eyepiece. Focal Length is the distance from the Objective Lens to were the light gathers to a single point. It is expressed as $M = F_o/F_e$, where M is magnification, F_o is the focal length of objective lens, F_e is the focal length of eyepiece. Greater magnification will let you see a larger picture.

4. A telescope has an objective lens with focal length of 1500 mm (millimeter) and an eyepiece with focal length of 25 mm. What is the magnification of this telescope?

____

Limit of Magnification

The magnification of a telescope can be changed just by changing the eyepiece. However, the light that comes in is limited, so if you magnify the image too much, you will start to notice the limit of image resolution. The maximum useful magnification is limited by the size of the objective lens.
$Max\ Useful\ Magnification = 50 \times D$, where D is the diameter of an objective lens in inches.

5. A telescope has an objective lens with diameter 4 inches. What is the maximum useful magnification?

Name____

____

6. In order for you to see a dim, but large deep sky object, you should use the telescope with greater (magnification or light gathering power). Explain your answer:

____

____

____

____

7. In order for you to see more details on relatively near bright object, you should use the telescope with greater (magnification or light gathering power). Explain your answer:

____

____

____

Types of Telescope

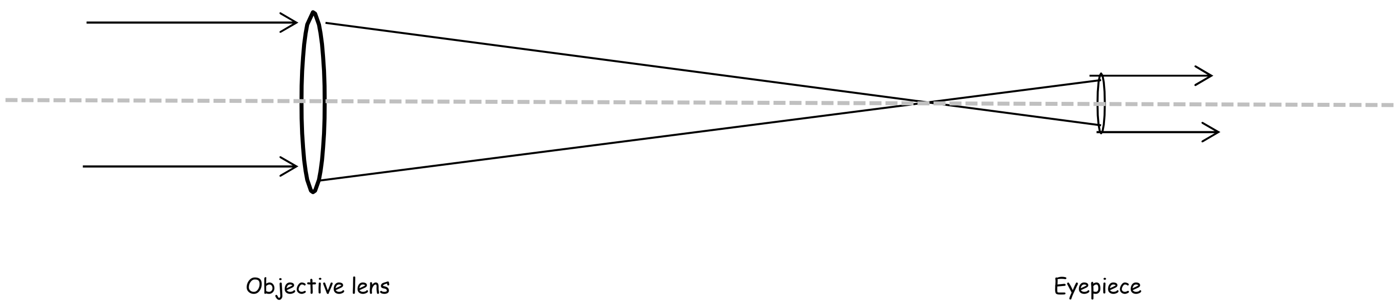
There are three main categories for the commonly used telescope.

- Refractor type Telescope – Galilean Telescope
- Reflector type telescope – Newtonian Telescope & Cassegrain focus Telescope and Catadioptrics.

Name_______________________________________

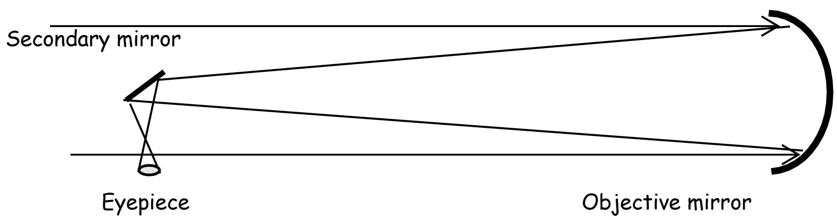
Galilean Telescope

Galilean telescope was first used in astronomy in 1608 by Galileo. It has an objective lens and an eyepiece. The amount of light you can gather depends on the size of the objective lens. For better light gathering power, the objective lens must be large. However, it is very difficult to make a large lens perfect, and a large lens made with glass can be very heavy. This design work fine for a smaller telescope, but it is not suitable for a larger telescope.



Newtonian Telescope

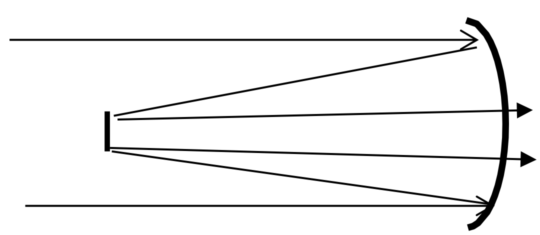
Newtonian telescope uses a parabolic objective MIRROR instead of a lens. The light focused by the objective lens is viewed with an eyepiece.



A large perfect concave mirror is easier to make than perfect convex lens. Therefore, a larger telescope was easier to make with this design.

Cassegrain focus Telescope

This telescope also uses parabolic objective mirror and a secondary mirror, but the eyepiece will be attached behind the objective mirror. The objective mirror will have a small hole in the middle to fit the eyepiece.



8. Which one of the designs will let you make smallest telescope for the same magnification?

Name____

____

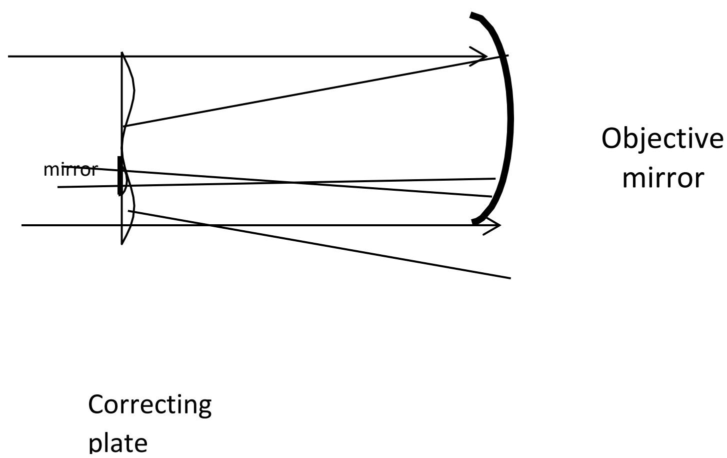
9. *For Newtonian and Cassegrain design, there is a mirror in front of the objective lens. Would you see the shadow of the mirror on your image? Explain your answer.*

____

Catadioptrics telescope

Catadioptrics telescope has a similar design to Cassegrain telescope. The important difference is in the shape of its objective mirror. Catadioptrics telescope used spherical objective mirror instead of parabolic mirror. The advantage of using spherical mirror is it is easier/ more economical to produce.

The problem with spherical mirror is the spherical aberration. To correct the spherical aberration, it has correction plate in front of the objective mirror.



Name____

Two Small Pieces of Glass:

Go to https://youtu.be/jqI28o1yOlA

What is the difference between refractor & reflector

What is "better resolution" mean? What do you do to achieve this?

List couple of things Galileo has discovered with his primitive telescopes?

What is chromatic aberration? Chromatic aberration issue in refractor lead to the invention of Newtonian telescope.

Who was Edwin Hubble? What did he contribute the advancement of astronomy?

List at least one major achievements by Hubble Space Telescope:

Name_________________________________

Telescopes

Study the telescope parts in the little blue book (pg 82 & 86):

Fill in the blank with one of the following: Declination clamp, Right ascension clamp, Declination slow motion knob, RA slow motion knob, Objective lens or mirror, Eyepiece, Focus knob, RA and Dec setting circle, View finder

(90 mm refractor shown)

1: ___________________________

3:___________________________

4. ___________________________

5. ____________________________

11. ____________________________

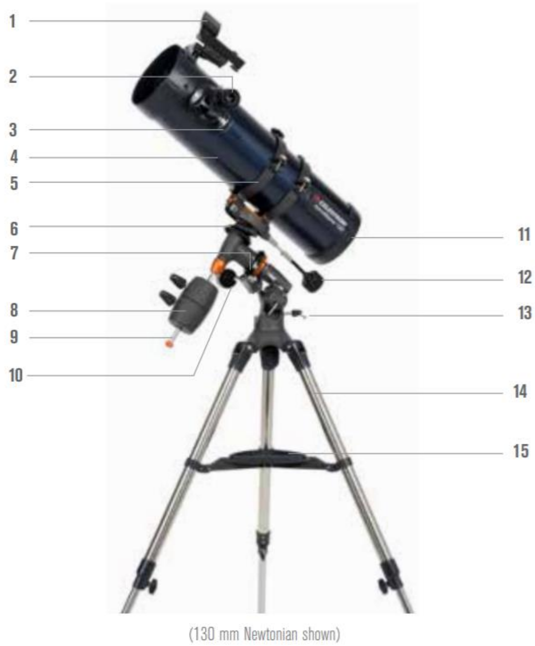
12. ____________________________

14 . ____________________________

15 . ___________________________

#17 is latitude adjustment knob and #8 is tripod.

Name___________________________________



(130 mm Newtonian shown)

1: ____________________________

2:____________________________

3. ____________________________

6. _____________________________

7. _____________________________

10. _____________________________

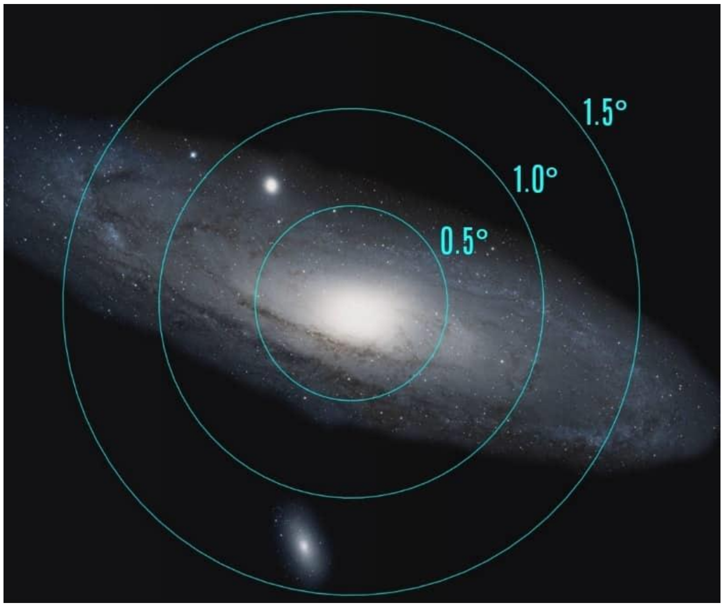
11 . _____________________________

12 . ____________________________

#13 is latitude adjustment knob and #14 is tripod.

Field of View

Field of view is the size of an object you can look at through a telescope. Field of view is an angular size. So the actual area and size you will be viewing will change depending on the distance of the object from you.



$$FoV = \frac{57.30\ (O)}{R\ D}$$

Where, FoV is Field of view in degree,

O is the actual size of the object

R is the % of the object within the view diameter

D is the distance of the object from you

*Field of view for a given telescope changes with the eyepiece that you use.

Name___________________________________

Part 2 - Telescope Simulation

Go to https://www.stelvision.com/en/telescope-simulator/. This simulation lets you change parameters of a hypothetical telescope and view various targets. First, we will sketch three objects.

10. First, keep your selection as “Simple Simulation”. For the Diameter of your telescope, type “203mm (8”). Record the Diameter of your telescope.

Aperture: ________________

11. For the choice “Select what you want to see”, select Moon, Saturn, and the Pleiades. Sketch them in the circles below.

Moon **Saturn** **Cluster**

“Moon

Click on “Detailed simulation: choose your eyepieces”.

12. For “Diameter of the instrument D”, type in 203mm. For “Focal length of the instrument F”, type in 1400mm. Below, select the left column, “I choose my eyepieces”. For the first eyepiece focal length, type 40mm. For the second eyepiece type 20mm. For the third eyepiece type 10mm. Leave the other eyepieces blank. For “Apparent field of view of eyepieces”, type 30°. For “Celestial sights”, select “Moon”. Click “Simulate”. Complete the table below.

8 in (203mm) aperture telescope

Eyepiece Focal Length	Magnification	True FOV	Object appears Largest, medium or smallest	Object appears Brightest, medium, or dimmest
40mm				
20mm				
10mm				

Name___________________________________

Which eyepiece resulted in greatest: Magnification - ______________________

Field of View- _______________________

13. Go back to setting the telescope parameter. Change the “Diameter of the instrument” to 152mm (6”). Change the “Focal length of the instrument” to 1220mm. Keep everything else the same. Complete the table below.

6 in aperture telescope – select “6in” aperture.

Eyepiece Focal Length	Magnification	True FOV	Object appears Largest, medium or smallest	Object appears Brightest, medium, or dimmest
40mm				
20mm				
10mm				

Which eyepiece resulted in greatest: Magnification - ______________________

Field of View- _______________________

14. Repeat for Diameter of 102mm (4”), Focal length of instrument of 1020mm.

4 in aperture telescope – select “4in” aperture.

Eyepiece Focal Length	Magnification	True FOV	Object appears Largest, medium or smallest	Object appears Brightest, medium, or dimmest
40mm				
20mm				
10mm				

Which eyepiece resulted in greatest: Magnification - ______________________

Field of View- _______________________

Name___________________________________

Let's summarize:

Circle the appropriate choice. "Telescopes with high magnification will have large/small field of view. Telescopes with low magnification will have large/small field of view."

Which telescope has greatest focal length of objective: __________________________

If you are observing a large object, which telescope with eyepiece would you use? ____ in, _______mm

If you are observing a very small dim object, which telescope with eyepiece would you use? ____ in, _______mm

Part 3: using the field of view equation.

You have a 6-in telescope with a focal length of objective of 1500mm. 2 eyepieces; 30mm and 15mm.

Find the magnification of the telescope with each eyepiece.

Eyepiece	Focal Length of Objective	Magnification unit: times (x)
30mm		
15mm		

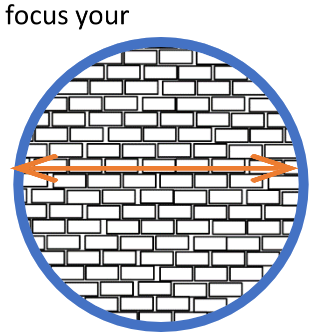
For the telescope above, 30mm eyepiece gives FoV of 0.5 degree and 15mm eyepiece is 0.25 degree.

If you know the field of view of the telescope-eyepiece system, you can use that information to find the distance to an object of a known size. We can re-write the equation for FoV.

$$D = \frac{57.30 \times O}{FoV \times R}$$

Where: FoV is Field of view in degree, O is the length of object observed in eyepiece, R is the % of the object within the view diameter, D is the distance of the object from you

You are looking at building 9 from the roof top observatory at building 60. When you focus your telescope on one of the bricks on the wall of building 9, this is what you see.



Count the number of bricks across in your view: _______________

Your measured R is equal to 1 / # of bricks you count. R = _______________

Name__________________________________

Width of the brick is 30.5cm. Convert this number to meter. This is O: ____________

You used the eyepiece with greater magnification. Which eyepiece? _______________

What is the FoV:__________

Use the data above to calculate the distance to building 4: Show your calculation.

Distance to building 4 is _________________________________.

Name___________________________________

The Solar System

In today's lab, we will study various properties (size, mass, density, temperature, etc) of planets.

Graphing the Planets

We will begin by graphing some properties of planets. For this part of the lab, the well-studied dwarf planet, Pluto, will be considered as one of the "planets".

The properties that we will plot are Mass, Rotation Period, Average Temperature, Distance from the Sun vs. Time to Orbit the Sun, and Inclination vs. Eccentricity of the Planet's Orbit. The graphing plots are at the end of the lab instructions. Use the table below to plot, then answer the following questions. For Distance vs. Time and Inclination vs. Eccentricity, make sure you label each planet.

Name	**Mass (Earth mass)**	**Average Distance from Sun (AU)**	**Time to Orbit Sun**	**Rotation Period**	**Average Temp (K)**	**Tilt of Rotation Axis (°)**	**Inclination of Orbit (°)**	**Eccentricity of Orbit**
Mercury	0.06	0.387	88 days = 0.24 yr	58.6 days = 1406 hrs	700(day) 100(night)	0.00	7.00	0.206
Venus	0.82	0.723	225 days =0.62yr	243 days = 5832 hrs	740	177.3	3.39	0.007
Earth	1	1.00	1 yr	24 hours	290	23.45	0.00	0.017
Mars	0.11	1.52	1.88 yrs	24.6 hours	210	25.2	1.85	0.093
Jupiter	318	5.20	11.9 yrs	9.93 hours	165	3.08	1.31	0.048
Saturn	95.2	9.54	29.4 yrs	10.6 hours	135	26.73	2.48	0.056
Uranus	14.5	19.2	83.8 yrs	17.2 hours	75	97.92	0.77	0.046
Neptune	17.1	30.1	164 yrs	16.1 hours	60	28.8	1.77	0.010
Pluto	0.002	39.5	248 yrs	6.39 days 153 hrs=	40	119.6	17.14	0.248

Graph: Mass vs planet (Semi-Log)

1. Which planet is the most massive? ____________________

2. Which planet is the least massive? ____________________
3. How do the masses of the gas giant planets compare to the masses of the terrestrial planets?

____

____

Name___________________________________

4. Which planet has a mass most similar to Earth?___________________________

Graph: Rotation Period vs. planet (Semi-log graph)

1. The rotation period marks the length of the sidereal day. What is a sidereal day? What is a solar day? Explain what these terms mean, not just how long they last. Read P. 71 of the little blue book.

2. Which planet has the shortest rotation period? ___________________

3. Which planet has the longest rotation period? __________________
4. How do the rotation periods of the giant planets compare with the rotation periods of the terrestrial planets?

5. You should have noticed that the gas giant planets were rotating very quickly. Aside from just shorter days, name at least one effect this fast rotation creates on the giant planets.

Graph: Average Temperature vs. planet (linear graph)

For Mercury, calculate the average temperature.

1. Which planet has the highest average temperature? ________________

2. Which planet has the lowest average temperature?_________________
3. Compare the average temperature of the planets to their average distance from the Sun – explain any trend that you may see. Does this trend make sense? Explain.

4. Notice that Venus does not follow this trend. What causes the exceptionally hot temperatures on Venus? Hint, P 645

Name___________________________________

Graph: Average Distance from the Sun vs. Time to Orbit the Sun (large graph paper)

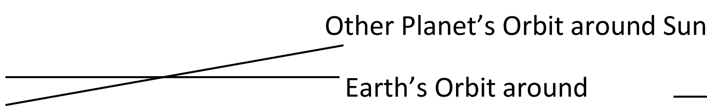
1. Which planets take longer to orbit the Sun; Those with smaller orbits or those with larger orbits?

2. Which of Kepler's Laws is this? How is that law normally written? Hint: P40

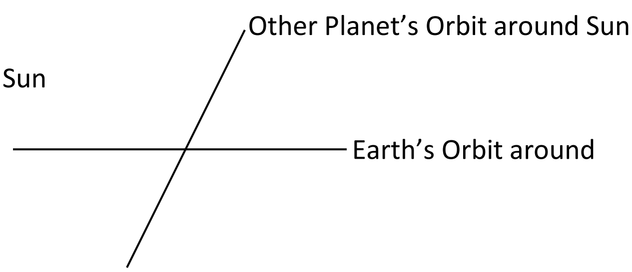
Graph: Inclination vs. Eccentricity of Orbits (use larger graph paper).

The inclination of a planet's orbit measures how tilted its orbit around the Sun is compared with the Earth's orbit around the Sun. An orbit with an inclination of 0º will orbit in the same plane as the Earth. An orbit with an inclination of 90º will orbit in a plane perpendicular to the Earth's orbit around the Sun. Here are examples of low and high inclination orbits:

Low Inclination



High Inclination



1. Which planet (besides the Earth) has the smallest inclination?

____

2. Is there one planet that has a significantly larger inclination than the rest of the planets? If so, what planet is this?

____

3. Eccentricity is a measure of how "oval-like" the elliptical orbit of a planet around the Sun is. An eccentricity of 0 is a perfect circle. An eccentric close to 1 has a more elongated orbit.

   a. Which planet has an orbit that is closest to a perfect circle?______________________

   b. Which planet has the most elongated orbit?_________________________

4. Do most planets have nearly the same eccentricity value? What is this value? What two planets have very different eccentricities than the rest of the planets?

Name________________________________

5. You should have noticed that your answer to question 2 and 3b are the same planet. This planet has an orbit that is very different from the other planets. Consider the Kuiper Belt – a collection of smaller icy rocks out past the orbit of Neptune. The Kuiper Belt is likely the source of many of the comets that we see. The eccentricities and inclinations for a few Kuiper Belt objects are shown below. Use a different color to add these Kuiper Belt objects to your eccentricity and inclination plot.

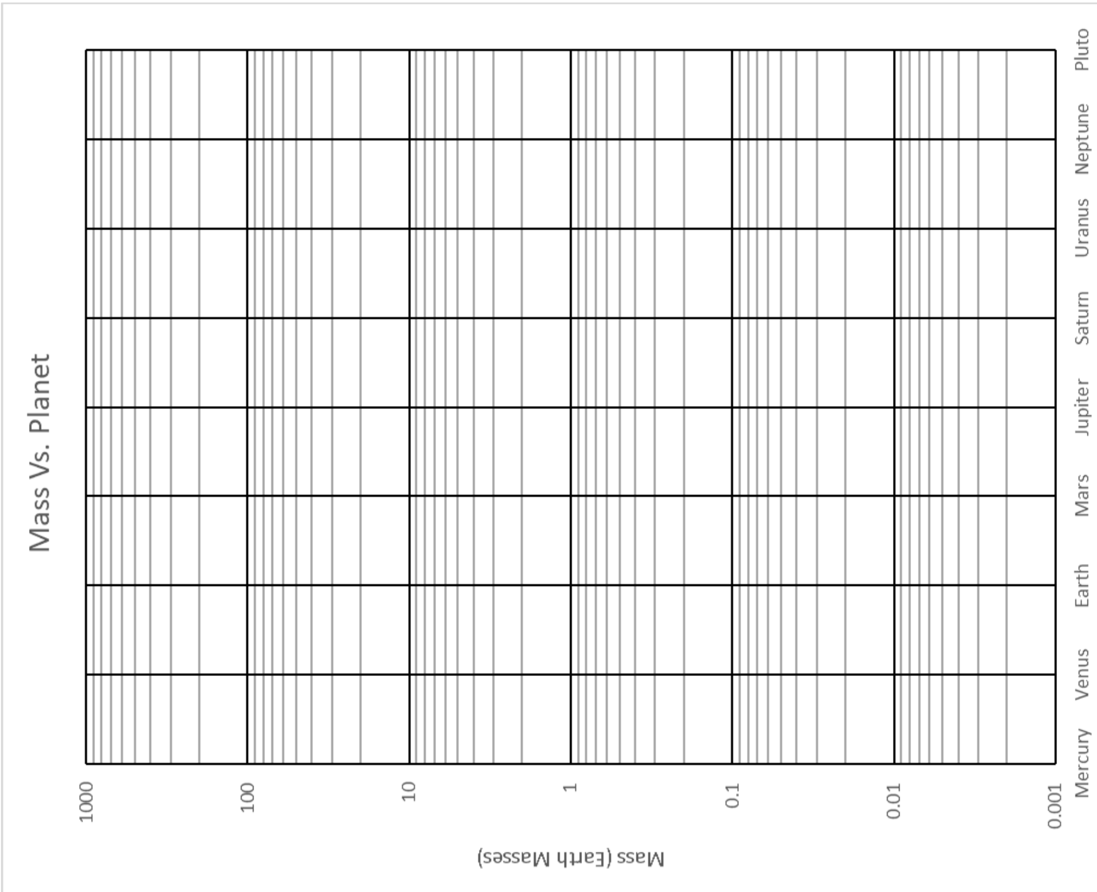
Inclination of Orbit	Eccentricity of Orbit
21.8°	0.150
17.9°	0.099
13.7°	0.122
1.5°	0.269
20.9°	0.042
28.5°	0.135
24.7°	0.270

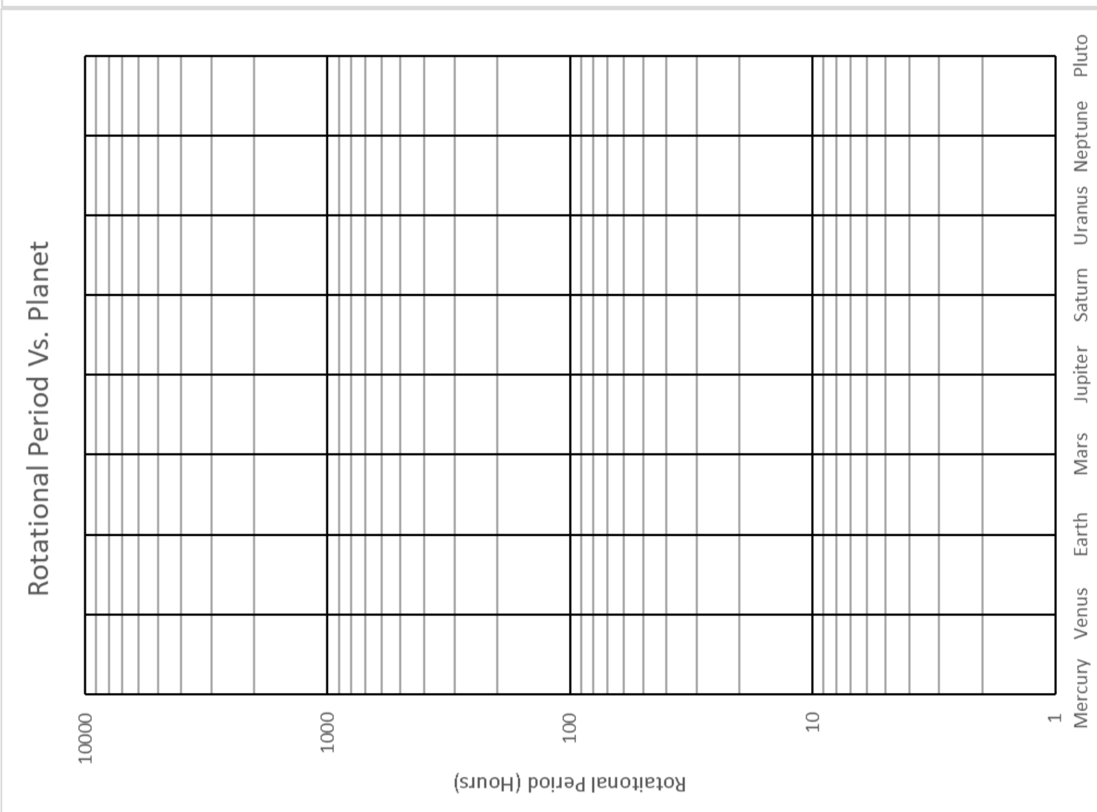
6. Is the inclination and eccentricity of Pluto more similar to the other planets or to the Kuiper Belt objects? What might this say about the nature of Pluto?

7. In August 2006, Pluto was demoted from planet to small object in solar system. List 3 reasons why this decision makes sense.

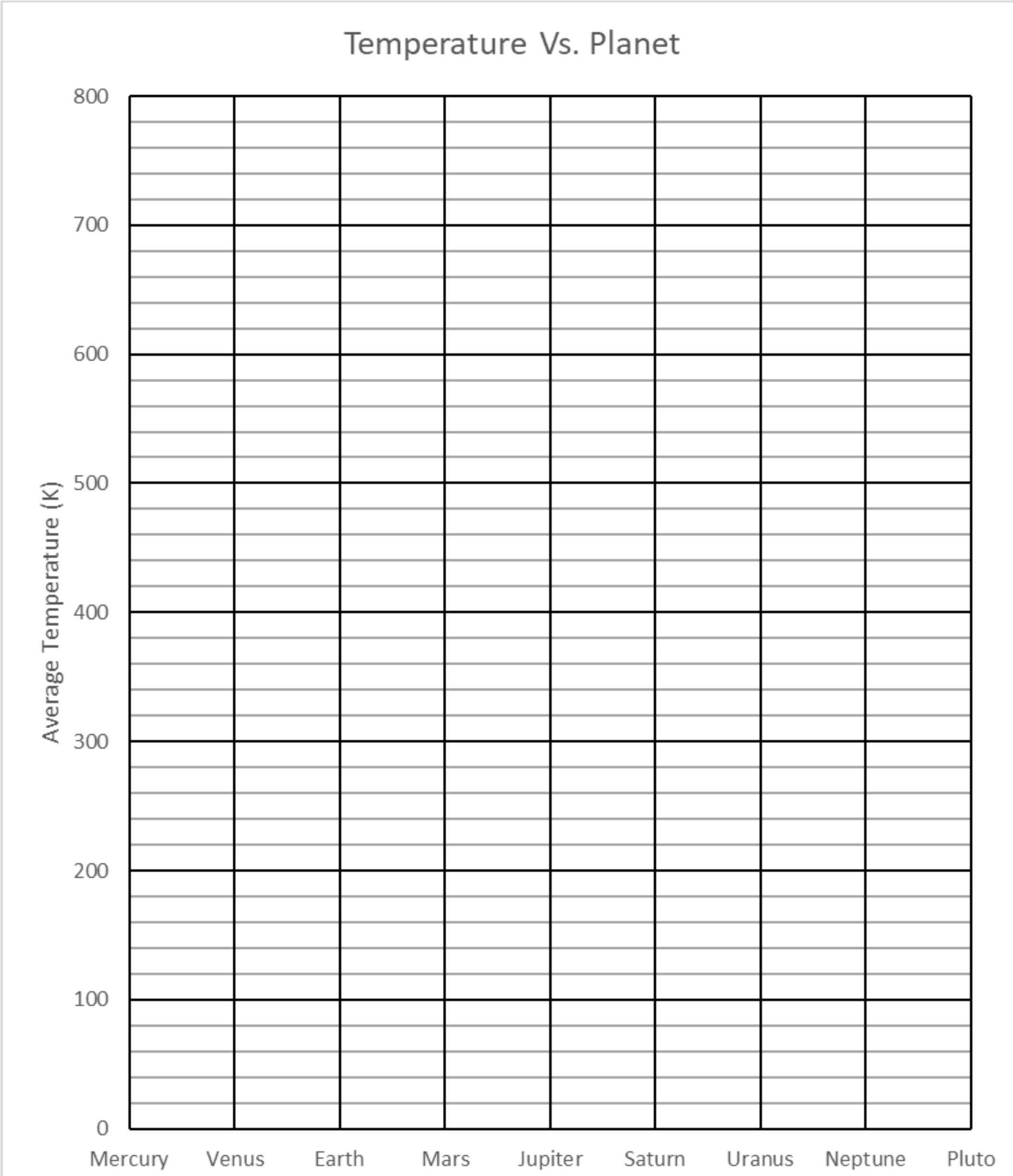
From this section on, Pluto is no longer a planet For all tables, show one example of work.

Name___________________________________

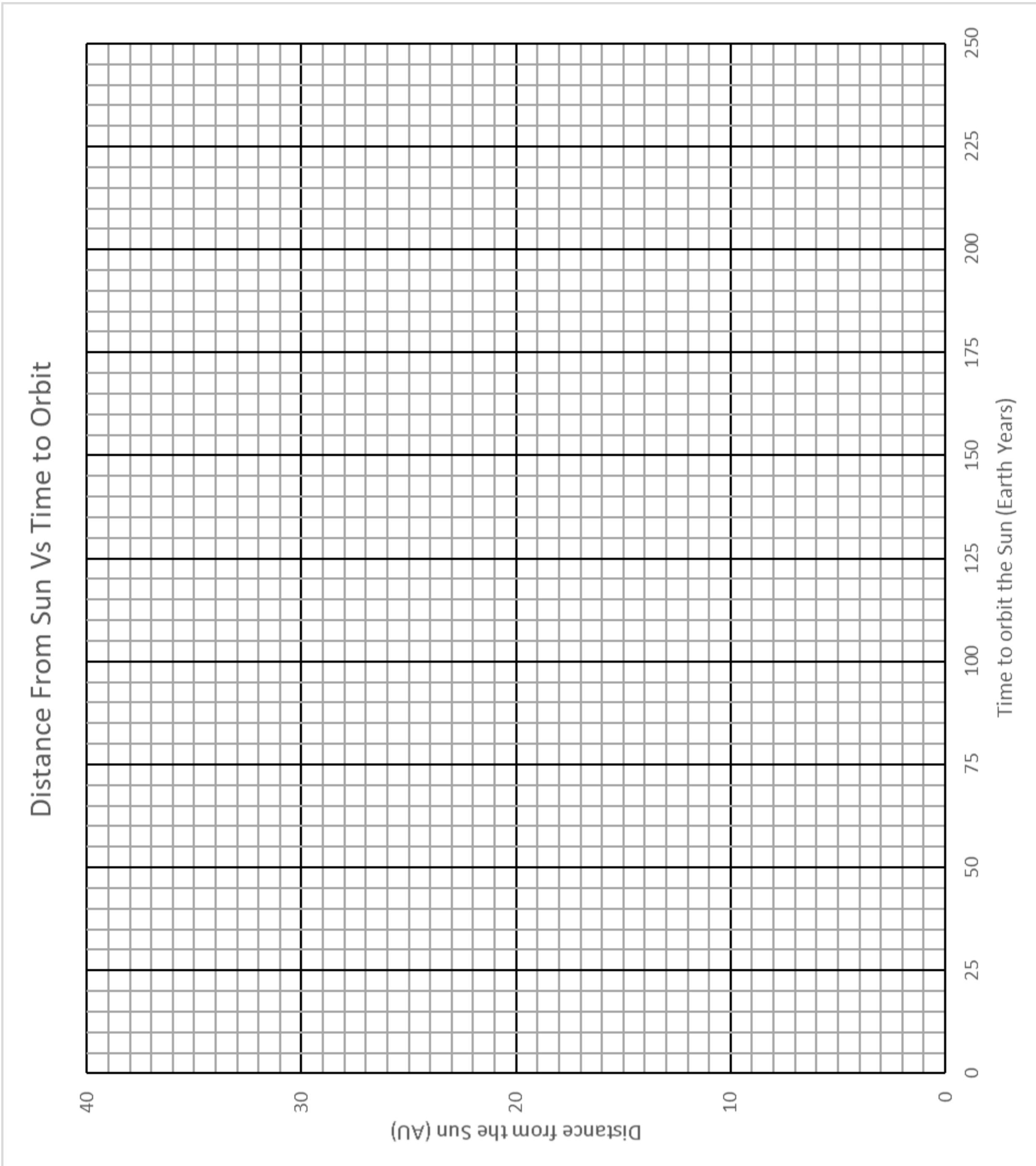

Mass Vs. Planet
Mass (Earth Masses)
1000
100
10
1
0.1
0.01
0.001
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto


Rotational Period Vs. Planet
Rotaitonal Period (Hours)
10000
1000
100
10
1
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto

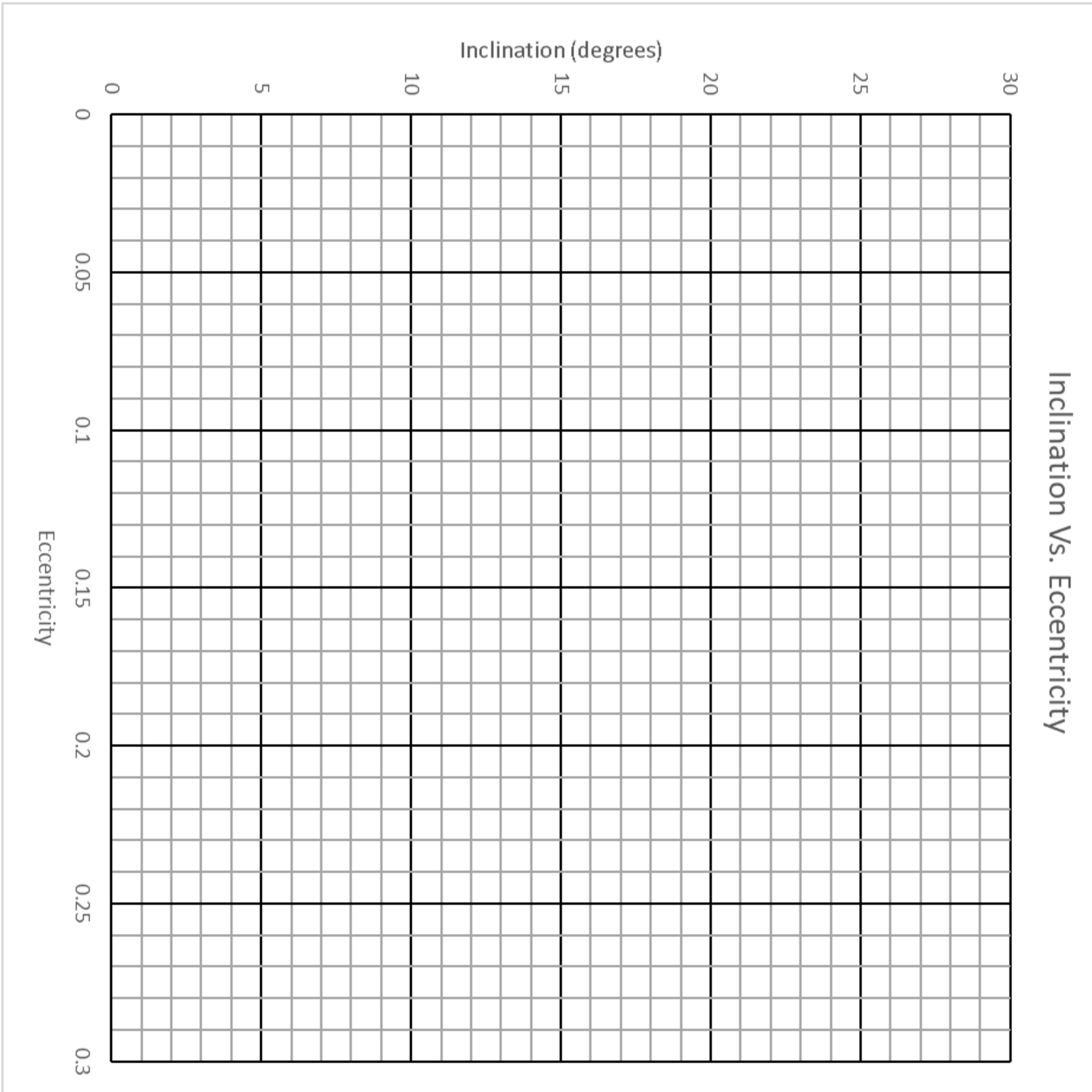
Name___________________________________


Temperature Vs. Planet
Average Temperature (K)
800
700
600
500
400
300
200
100
0
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto

Name___________________________________


Distance From Sun Vs Time to Orbit
Time to orbit the Sun (Earth Years)
0
25
50
75
100
125
150
175
200
225
250
Distance from the Sun (AU)
0
10
20
30
40

Name___________________________________


Inclination Vs. Eccentricity
Inclination (degrees)
0
5
10
15
20
25
30
Eccentricity
0
0.05
0.1
0.15
0.2
0.25
0.3

Name___________________________________

Scaling the Solar System, Part 1

Distance to the Planets

Outside we are going to create a scale model of the solar system. The distance between the Earth and Sun will be 150 cm in this scale model. Use the table below, to calculate the model distance to each planet in this scale model and record your answers in the table. Rearranging the equation from before we get:

$$Distance\ of\ Planet\ in\ Model = DIstance\ of\ Earth\ to\ Sun\ in\ Model \times \frac{Actual\ Distance\ of\ Planet}{Actual\ Distance\ of\ Earth\ to\ Sun}$$

Planet	Actual Distance from Sun to Planet (in AU)	Distance to Planet in Model
Mercury	0.387	
Venus	0.723	
Earth	1.00	
Mars	1.524	
Jupiter	5.203	
Saturn	9.539	
Uranus	19.19	
Neptune	30.06	

One example of work.

Name________________________________

1. Which type of planet (terrestrial or gas giant) is located farther from the Sun?

____

2. Is the distance between each planet the same? How does the distance between the planets change as you go farther from the Sun?

____

3. The closest star to the Sun is 4.2 light years away. Calculate the model distance to Proxima Centauri using the scale. Then, convert this distance into kilometers and miles. 1 light year = 63,000 AU, 1 mile = 1.609 km

____

Weight on a Planet

We will now find out how much you would weigh in you were on the surface of each planet. Before you do any calculations, answer the following questions:

1. What planet do you think you will weigh the most on? Why?

---

2. What planet do you think you will weigh the least on? Why?

Your weight on the surface of a planet is a combination of the mass of the planet and the radius of the planet. You can calculate your weight on each planet using the following equation:

$$Weight\ on\ a\ Planet = Your\ Weight\ on\ Earth \times \frac{Mass\ of\ Planet\ compared\ to\ erath}{Diameter\ of\ Planet\ compared\ to\ Earth^2}$$

3. Imagine that the diameter of the Earth is twice as big as it is now, but still the same mass. If you weigh 100 pounds right now on Earth, how much will you weigh on Earth with the larger diameter? Show your work and write your answer with the correct unit.

Name_________________________________

For each planet, calculate the weight of a 100 pound person. Record your answers in the table below with the correct unit. Keep three decimal points. Show one example of work.

Planet	Mass of Planet Compared to Earth	Diameter of Planet Compared to Earth	Weight on Planet
Mercury	0.055	0.382	
Venus	0.815	0.949	
Earth	1	1	
Mars	0.107	0.533	
Jupiter	317.9	11.19	
Saturn	95.18	9.46	
Uranus	14.54	3.98	
Neptune	17.13	3.81	

4. Which planet would you be the heaviest on? Which planet would you be the lightest on?

____

5. Imagine that you could go to any planet and take part in a high jump competition. Which planet will you jump the highest on?

____

Scaling the Solar System, Part 2

Size of the Planets

We are now going to make a scale model of the sizes of planets in our solar system.

1. First on the back of the page, estimate and draw the relative sizes of Jupiter, Earth, and Mercury. You can use the table and plot from earlier to make an educated guess. Write down your reasoning for drawing in this way.
2. On the board you will see a drawing of the Sun. What is the diameter of the Sun in the Model?

_________ centimeters.

Name________________________________

To figure out how big other planets are in this scale model, we can use the following relationship:

$$\frac{Diameter\ of\ Planet\ in\ Model}{Actual\ diameter\ of\ planet} = \frac{Diameter\ of\ Sun\ in\ Model}{Actual\ diameter\ of\ Sun}$$

Rearranging this will give us

$$Diameter\ of\ Planet\ in\ Model = Diameter\ of\ Sun\ in\ Model \times \frac{Actual\ Diameter\ of\ Planet}{Actual\ Diameter\ of\ Sun}$$

3. The "actual diameter of the planet" and the "actual diameter of the Sun must be in the same unit". The "diameter of the planet in the model" will be in the same unit as the "diameter of the Sun in the model". Use the table below to calculate the diameter of each planet in the model.

The actual diameter of the Sun is 1,392,000 km. Show one example of work.

Planet Name	Actual Diameter of Planet (in km)	Diameter of Planet in Model
Mercury	4,878	
Venus	12,102	
Earth	12,756	
Mars	6,794	
Jupiter	142,984	
Saturn	120,536	
Uranus	51,118	
Neptune	49,528	

Name_________________________________

Size Predictions: Jupiter, Earth, Mercury

Name________________________________

Correct sizes: Jupiter, Earth, Mercury

Name___________________________________

4. Earlier in part 1 you drew circles to estimate the size of Jupiter, Earth, and Mercury. Measure the diameters of the estimated circles for the three planets and include them in the table below. Then copy the calculated diameter of the planet in the model from the table in questions 3. For each of the three planets, was your estimate too small or too large? By how much? Draw the correct size circle on the back.

$$how\ much\ too\ large\ or\ small = \frac{Larger\ of\ the\ the\ two}{Smaller\ of\ the\ two}$$

Show one example of work.

Planet	Diameter of Circle You Drew	Diameter of Planet in Model	Estimate Too Large or Too Small?	Too Large or Small by how much?
Jupiter				
Earth				
Mercury				

5. Which planet were you the most accurate in your estimate?

____

6. Are you surprised by the model size of the planets? Explain why or why not.

___

___

___

7. Calculate the distance from the Earth to the Moon in this model. The Moon is 384,400 km from the Earth. Use the same equation, but this time instead of the actual diameter of the planet, you will put in the actual distance from the Earth to the Moon.

8. Calculate the distance from the Earth to the Sun in this model in meters. The actual distance to the Sun is 1 AU = 1.5×10^8 km from the Earth.

Name________________________________

Answer the following questions:

8. Which type of planets (gas giant / terrestrial) are the largest?

____

9. Which is the largest planet?

____

10. Which is the smallest planet?

____

11. How many times bigger is the Sun compared to Earth?

____

12. How many times bigger is the Sun compared with Jupiter?

13. How many times bigger is Jupiter compared with the Earth?

Mass of the Planets

On the table from the first section page, the masses of the planets in our solar system are listed compared with the mass of the Earth.

1. List the 8 planets in order from the most massive to least massive (do not include Pluto).

2. If you were to list the planets in order from the largest to the smallest in size, would it be the same order? If not, what would be different?

Name___________________________________

Density of the Planets

The density of an object measures how tightly packed its weight is.

1. Density is

$$Density = \frac{Mass}{Volume}$$

Which type of planets do you expect to have the highest densities; Terrestrial or Gas giants? Explain why.

---

2. For each planet, calculate its density using the following equation – This equation is modified from above to compare everything to the Earth.

$$Density\ (in\ \ g/cm^3) = \frac{5.5 \times Mass\ of\ Planet\ Compared\ to\ Earth}{(Diamter\ of\ Planet\ Compared\ to\ Earth)^3}$$

Record your answers in the Table below. Show one example of work.

Planet	Mass of Planet Compared to Earth	Diameter of Planet Compared to Earth	Density (in g/cm3)
Mercury	0.055	0.382	
Venus	0.815	0.949	
Earth	1	1	
Mars	0.107	0.533	
Jupiter	317.9	11.19	
Saturn	95.18	9.46	
Uranus	14.54	3.98	
Neptune	17.13	3.81	

Answer the following questions:

3. Which planet has the largest density?

____

4. Which planet has the smallest density?

____

Name________________________________

5. Which type of planets have the larger densities; terrestrial planets or gas giants? Is this what you expected?

---

6. Look back to "Weight on a Planet", question 2. Was your initial guess correct? If not, explain why you think you were wrong initially.

---

7. Explain why the planets with the most mass and the largest diameters don't have the largest densities. Hint: Think about what the different types of planets are made of.

---

8. The density of water is 1 g/cm^3. If something has a density less than water, it will float on water. Which planet will float on water?

Name_________________________________

Kepler's Laws, Jupiter's Moons

Starry night: Kepler's laws:

In this section, we will investigate Kepler's second and third laws of planetary motions.
Kepler's laws are:
(1) Planets move around the Sun in ellipses, with the Sun at one focus
(2) The line connecting the Sun to a planet sweeps equal areas in equal times.
(3) $p^2 = a^3$: The square of the orbital period of a planet is proportional to the cube of the mean distance from the Sun

Explain what each of the 3 laws mean in your own words. Hint: p. 40

1:____

2:____

3:____

Kepler's 1st law

Use the ellipse demonstrator to learn about how ellipses and eccentricity works. Open Class Action. From "All Moduels" -> "Renaissance Astronomy". From the bottom menu, "Animations" -> "Eccentricity Demonstrator".

1. Define: ellipse and eccentricity.

___

___

2. What values can eccentricity have?

____

3. What is the ellipse's shape when e=0? _______________________________
4. How does the shape change as eccentricity increases and approaches 1?

___

6. Most planets have eccentricity of less than 0.1. How would you describe an ellipse with e=0.1? Close to a circle or not?

____

Name_______________________________

Starry Night

Start Starry night. Stop flow of time Under Option tab:
Guides: turn all options off, Local view: turn all options off, Solar system: select planets and asteroids only, Stars: turn all options off, Constellations: turn all options off, Deep space: turn all options off.
Under Find tab:
Double click on "sun", this will shift your gaze so you are pointed at the sun and will put a label near the sun. Click both boxes for earth. This will show earth's orbit and label its position.
From the top menu, "Option" -> " Viewing location" select "Stationary location". Change Cartesian coordinates to X:0au, Y:0au,Z:4au.

1. Create an asteroid by "file" -> "New Asteroid orbiting the sun". A sub-window will appear.

Change the name to a unique name: ___________________________

Under orbital elements: mean distance (a) = 1.0au, eccentricity (e) = 0.75, leave the other numbers as it is. When you close this window, you will be asked if you want to save the changes. Click on "save

2. Find your newly created asteroid using "find". Check both boxes next to the name. From now on in this manual, your asteroid will be referred to as "X".
3. Using the Kepler's 3rd law, determine the orbital period of this asteroid. Show your work and units.

4. Should the orbital period depend on the eccentricity? Explain.

____

____

____

5. If we had created an asteroid with mean distance 2au, what would the orbital period be? Show your work and units.

6. Now you have earth and asteroid X's orbital path displayed in your view. The orbits intersect at 2 places. Change the time step to 1 day and let the time run for at least one complete orbit.
7. Go to a date when X crosses earth's orbit. When you get close to an intersection you need to change the time step to smaller than 1 day to achieve accurate time. Record the date and time of intersection and circle the correct choice.

time& date of intersection_________________________ X is entering/exiting Earth's orbit.

Name___________________________________

8. Go forward in time to the other intersection.

time & date:__________________________ X is entering/exiting Earth's orbit.

9. Continue going forward in time to go back to the original intersection.

Note the time& date: _____________________________________

10. See your result from 7, 8, and 9. How many months did X spend inside of earth's orbit? How many months did X spend outside of earth's orbit?

____

11. Did X spend more time outside or inside? Does your result make sense according to Kepler's 2nd law? Explain your answer:

____

____

____

12. what was the orbital period of X?

____

13. Does this orbital period agree with the result from 3? Explain. Was it consistent with your answer to #4? If not, explain.

____

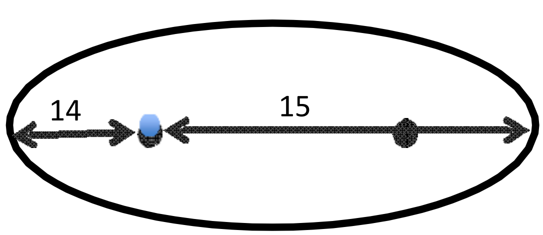
14. Go forward in time to place X at perihelion, a location in orbit closest to the sun. Place the "hand" over the asteroid to see the distance from the sun: OR open Info tab on the left hand side and see the distance under Position in Space.

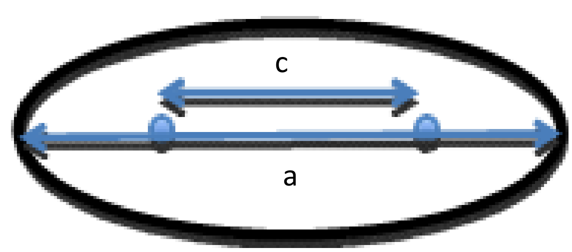
distance at perihelion: ____________________________

15. Go forward in time to place X at aphelion, a location in orbit farthest from the sun.

Distance at aphelion: _____________________________

16. Using the result from 14 and 15, determine c and a of X's orbit. a=14+15, c = 15-14.





a:___________________, c: _______________________

Name___________________________________

17. Knowing the eccentricity of X, does the answer in the previous question make sense? Explain your answer. Use the fact that e = c/a.

Moons of Jupiter

Galileo was the first person to realize the planet Jupiter has satellites. Let's go back in time to observe what Galileo observed. In 1609, Galileo had made a telescope modeled after earlier design of telescope invented by Hans Lippershey in the Netherlands in 1608. Lippershey's telescope was only 3 times the magnification, but by the end of 1609, Galileo made a telescope with 20x the magnification. In early 1610, Galileo observed Jupiter and discovered the satellites. Today, we will look into what Galileo would have seen with his telescope.

Stop flow of time. Under Option tab:
Guides: turn all options off, Local view: turn all options off, Solar system: turn on Planets-moons. Leave the planets-moons labels off for now.
Stars: check stars on, everything else off. Expand the stars option, hover over Limit by Magnitude and double click. A window will appear. In this window click the check box next to Limit Stars By Magnitude, in the box right of the slider box, type in 7.00 then OK. Deep space: turn all options off.
Let's go to Galileo' s town: Options-> Viewing Location to go to Padova, Veneto, Italy. Under find tab, check Jupiter, Set the day to January 7th, 1610. At the top right, Zoom into 1 degree by checking "sample 4"rfractor 25mm possl (1°)".
Advance the time one day at a time to sketch Jupiter and the satellites from 1/7/1610 to 1/14/1610.

Date	Time	Sketch
January 7th, 1610	8pm	
January 8th, 1610	8pm	
January 9th, 1610	8pm	Bad weather. There was no observation that night.
January 10th, 1610	8pm	
January 11th, 1610	8pm	
January 12th, 1610	8pm	

Name_________________________________

January13th, 1610	8pm	
January 14th, 1610	8pm	

1. Seeing the moon in motion, what evidence is there to tell you that they move around Jupiter, even though you cannot see the orbit itself?

2. Go to January 19th, 1610. Sketch Jupiter and its surroundings. What are the names of the moons? Label them in your sketch (under "Find" click on Labels box next to Planets-Moons to add labels).

3. Change the time step to one hour. Advance time to observe the motion. Which satellite is closest? Farthest?

____

4. Which moon moves the fastest? The slowest?

____

5. Go forward & backwards in time to determine the orbital period of the 4 satellites. For far away satellites, try turning off other labels and advance time in days.

Name of the satellite	Orbital period	Name of the satellite	Orbital period

6. Review your answer from 3 and 4. What is the relationship between the distance and orbital period? How is it consistent with Kepler's laws? Which of Kepler's laws?

Name ____

Google Earth and Crater measurement lab

Part A: Finding locations and using Latitude and Longitude

*Throughout this lab: Remember that for latitude positive number means north, negative number means south. For longitude, positive number means East and negative number means West. For each pair of coordinates, if it doesn't say "NSEW" pay attention to the value of the coordinate.

Open Google Earth program Find MtSAC by searching in the search box. (1100 north Grand Ave. Walnut CA 91789)

1. What is the latitude & longitude?

Latitude: _________________, Longitude: ____________________

2. Go to: 40.6889,-74.0444

What did you find there? If you don't know what it is, describe what you see: (Zoom in to at least altitude 500ft)

____

Looking at the longitude and latitude of this location, describe this location relative to Mt. SAC. Write your answer as "This location, _________________, is _____________ degrees West / East / North / West of MtSAC".

Compare latitude: ____

Compare longitude: ____

3. Go to: 51.1788,-1.8262.

What did you find there? If you don't know what it is, describe what you see: (Zoom in to at least altitude 500ft)

____

Looking at the longitude and latitude of this location, describe this location relative to Mt. SAC.

Compare latitude: ____

Compare longitude: ____

Go to a place of your choice.

4. If there is one place you could visit on earth where would that be? Why?

Name ____

5. What is the latitude & longitude of this location?

Latitude: _____________________, Longitude: _________________________
Looking at the longitude and latitude of this location, describe this location relative to Mt. SAC.

Compare latitude: ____

Compare longitude: ____

Part B, Craters

Let's take a look at Manicouagan impact crater: 51° 23′ N 68° 42′ W (51.4, -68.7). Zoom out to the eye altitude of at least 75 miles. Zoom in / out to see the crater (make sure you have your Navigation control on: View-> Show Navigation -> Automatically) To keep your view clean, to: "Layers", "Primary Data Base" and unclick everything.

1. Describe the appearance of Manicouagan today. Sketch in the box

2. What is the diameter of the crater? Use the Ruler tool by clicking on the ruler icon at the top of the view. Be sure to measure the diameter in kilometers.

____

3. If you live inside of this crater today, do you think you would know that you live in an old crater? Explain your answer.

Name ____

4. Go to http://pirlwww.lpl.arizona.edu/~rbeyer/crater_p.html to determine the size of the object created this crater.

Use:
Crater diameter: in km, Diameter is “Final”
Projectile Descriptor, projectile density: “Iron”
Impact condition: Impact Velocity is “Earth & Moon asteroidal impact”
Impact angle: type 90 Degrees
Target Descriptors: Target Density is “Porous rock”
Acceleration: Use your logic, Target type: “competent rock or saturated soil”
Use Yield Scaling as the diameter of the object.

5. Diameter of the object was: ____________________________ (Be sure to include an appropriate unit)
6. Is this object closest in size to: (circle one)

coffee cup car large bus MtSAC campus LA county North America continent

Let’s take a look at Barringer Meteor crater: 35° 1′ 38″ N 111° 1′ 21″ W (35.025,-111.025) Zoom out to see the entire crater.

7. What is the diameter of the crater? _________________________km
8. Explain why and how this crater will eventually be “erased” from the surface of the earth.

____

____

9. Determine the diameter of the size of the object created this crater.

Diameter of the object was: ___________________________Be sure to include an appropriate unit

Is this object closest in size to: (circle one)

coffee cup car large bus MtSAC campus LA county North America continent

Part C: Moon

Click on the icon next to the ruler tool icon to go to the moon. Under Primary Databases, click off everything except for “featured satellite images” and “place names” to keep your view simple.
Use the hand to move the moon around. Go all the way around and come back to the position that latitude& longitude 0 is at the center of your view. You can type in “0,0” in the search bar to go to this location, but you have to zoon out to see the entire Moon.

1. You notice there are darker part of the surface (Lunar Marina) and lighter part of the surface (Lunar Highlands). Zoom in to investigate the surface features of each part. Describe the difference in surface features you see on each part. Which side (darker/ligher) has more craters? Which surface is older? Answer in terms of the smoothness of the craters, lack of rays, density, etc.

____

Name ____

---

2. Look at the Far Side of the Moon (Longitude 180 and latitude 0 at the center of your view). What do you notice about the surface features compared to the other side of the moon?

Visit this location on the moon: 26° 42′ N 13° 07′ W (26.7N, -13.1)

3. What is the name of the crater? ___________________________________

4. What is the diameter of the crater? ___________ km

5. Determine the diameter of the object creating this crater. Include units.: _____________

Make sure you change the properties to match the situation.

6. Study the inside wall of the Crater. What do you notice about this crater compare to the Barringer crater you investigated earlier?

Go to $51^0$16’35” N, $9^0$19’W(51.60N, -9.4). Zoom our, and click on the small blue square. Be patient, and a flash video made by Kaguya team should pop up. Watch the video & enjoy the beautiful high resolution picture! If you cannot hear, you may need to go to youtube.com and search for KAGUYA taking around "Plato basin" by HDTV

7. What is the composition of Plato’s basin? How the basin was formed?

After watching the video, on the top left corner click on “back to Google Earth”. Go to 21^o48’N 17^o56”E (21.8N, 17.9E) OR Go to 10^o32’S 14^o19”E (10.5S, 14.3E) circle your choice.

8. Study the inside wall of the crater. What do you see (or don’t see) on the wall so the crater? Is it different from the Barringer crater that you looked at earlier?

Name ____

Part D: Go to Mars

Go to Mars. Under Layers, check the following items
Primary Database: Featured Satellite images & Place Names.
Mars Gallery: Expand the Guided tours, Double click on “introduction to Mars with Ira Flatow” (~8min)

1. What did we know about mars before the telescope?

____

____

2. What was the contribution of Giovanni Virginio Schiaparelli?

____

____

____

3. Which US missions were the first to systematically map this red planet?

____

____

4. What is Olympus Mons? What type of volcano is it? What did you learn about Olympus Mons?

____

____

____

5. What two events caused the markings on the edge of the lava flows?

____

6. How did Valles Marineris formed?

____

____

7. What kinds of formations are signs of visible evidence that there once was a lot of water on mars?

____

____

Name ____

Use the hand to move Mars around. Explore for a bit then go to the back to position so that latitude& longitude 0 is at the center of your view.

8. What do you notice about the surface features of Mars?

Go to 36.5°N, 107.75°E, this is a beautiful crater in northwestern Elysium Planitia in the Martian northern hemisphere. This image was taken by HiRISE camera on MRO.

9. What is the diameter of this crater? (units!)

____

10. Determine the diameter of the object creating this crater.

____

The object is closest in size to: (circle one)

coffee cup   car   large bus   MtSAC campus   LA county   North America continent

11. Study the inside wall of the Crater. What do you see (or don't see) on the wall of the crater? Is it different from the Barringer crater that you looked at earlier?

12. What can you say about the Martian geological activity and water environment, past and present?

Name ____

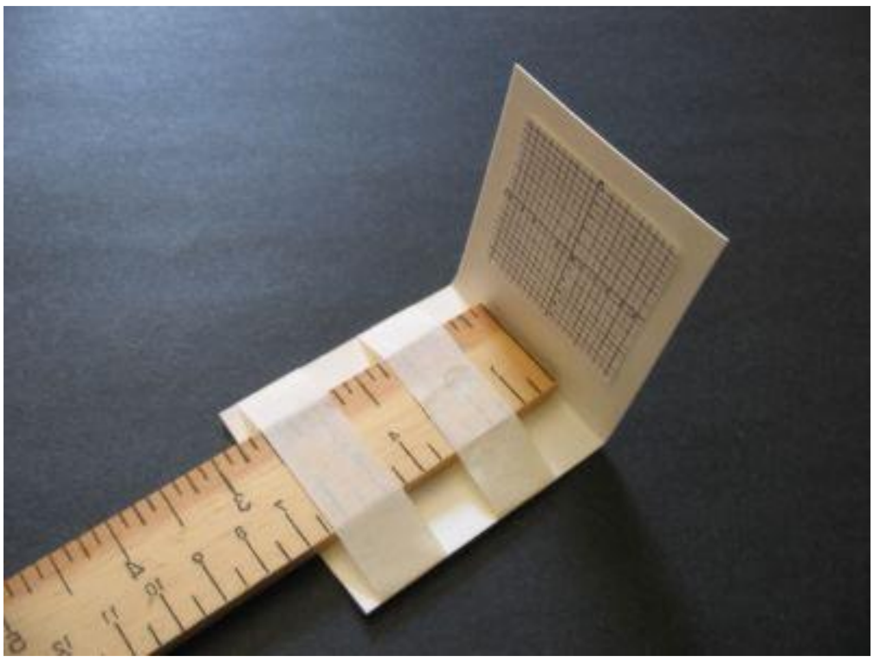
The Sun

Finding the diameter of the Sun (pinhole)

We will determine the diameter of the Sun using a simple card with a pinhole. Sunlight entering the pinhole will create an image of the Sun (not the pinhole!). By determining the size of the image, and knowing the distance to the Sun, we can determine the diameter of the Sun.

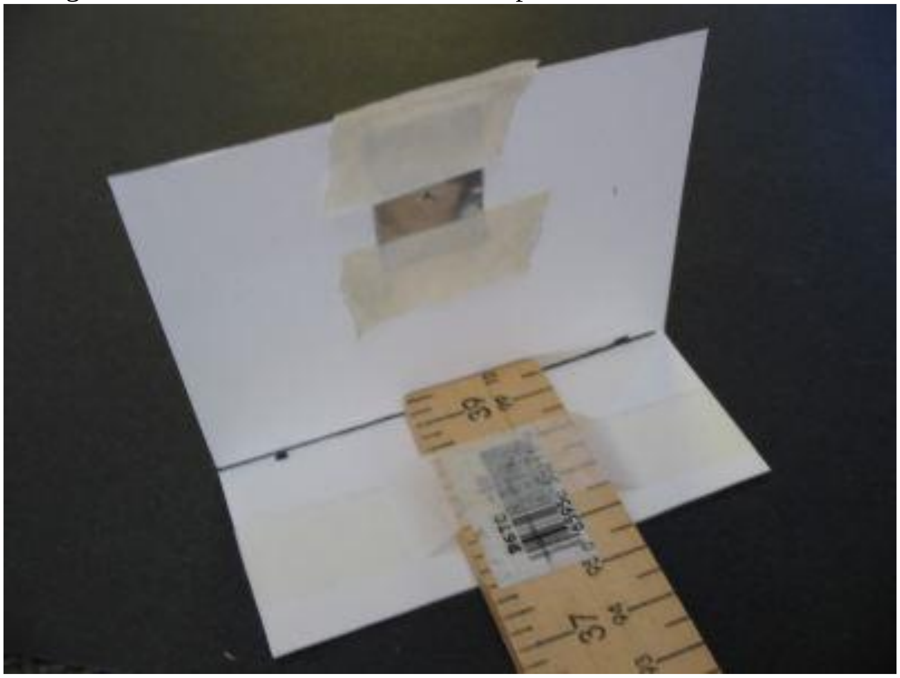
Procedure

1. Choose a straight stick. Your stick should be straight so that you can tape two pieces of paper and arrange it like the picture in the next page. I have used a long wooden spoon with success. Measure the length of the stick in meters and record it.
2. Print the graphing paper and glue it on a card. Or you can use a ruler and draw your own grid. Tape it to one end of your stick. Use a ruler to determine the size of one square grid in milimeter. Record this in the data table.

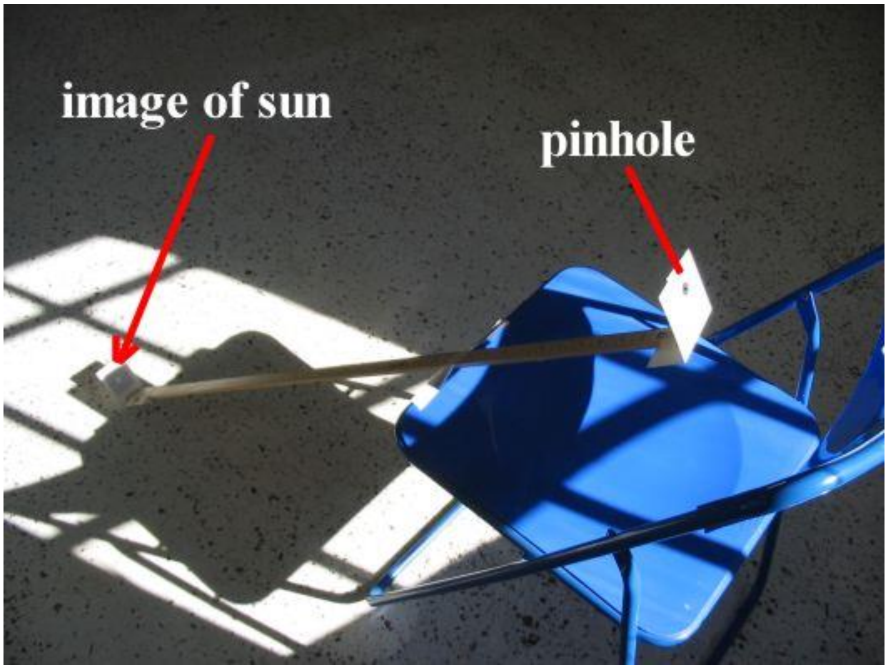


Name ____

3. Take another card, and tape a piece of aluminum foil on it. Use a pushpin to poke a small hole through the aluminum foil and the card. Tape this card to the other end of the stick.



4. Point the pinhole towards the Sun, so that you see an image of the Sun on the grid. Note that what you are seeing is the image of the Sun, not the shape of the pinhole!

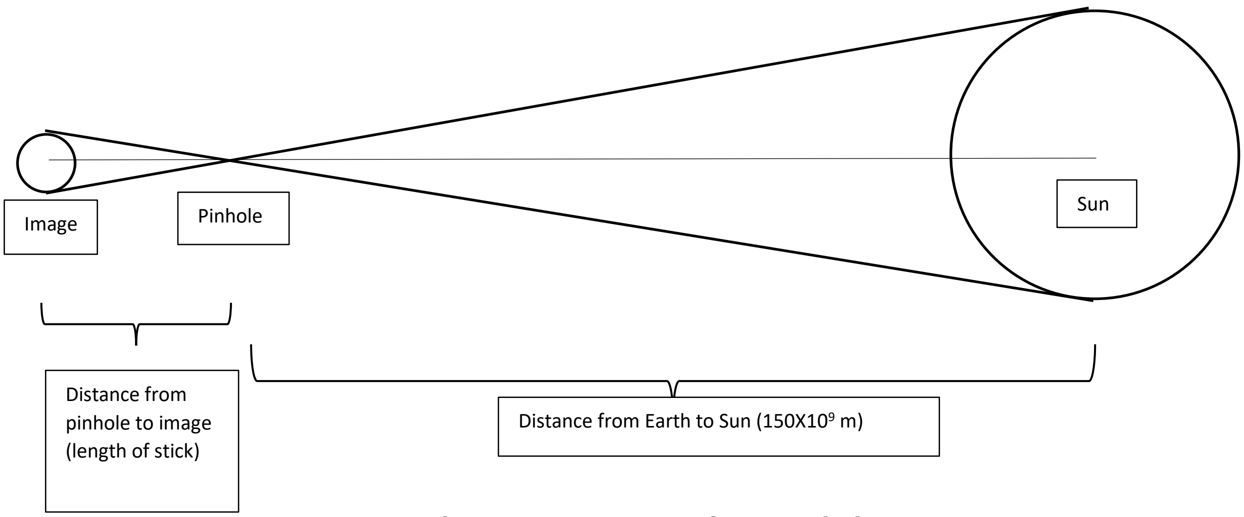


5. Count how many grids the image of the Sun occupies. Then the diameter of the image will be $(the\#of\,grids) \times (the\ size\ of\ each\ grid)$. Calculate the diameter of the image in millimeter and record this on the data table. Show work for finding the diameter of the image.

Take a picture of your contraption, and upload it with the completed lab.

Name ____

The diameter of the Sun can be determined using geometry.



$$\frac{Diameter\ of\ image}{Diameter\ of\ Sun} = \frac{Distance\ from\ pinhole\ to\ image}{Distance\ to\ Sun}$$

This becomes $Diameter\ of\ Sun = \frac{150\times10^{9}m}{\text{length of stick (m)}} \times Diameter\ of\ image$

Equation 1

This equation will give you the diameter of the Sun in millimeter. To convert to kilometer, $kilometer = milimeter \times 10^{-6}$

Equation 2

6. Use Equation 1 and Equation 2 to determine the diameter of the Sun in millimeters then kilometers. Keep two decimal points. Show work for determining the diameter in mm, and converting to km in the space below.

Name ____

Size of one grid (mm)		Diameter of the Sun's image (mm) with work	
# of grids the image occupies		Calculated diameter of Sun (mm) with work	
Length of stick (m)		Calculated diameter of Sun (km)	

7. The actual diameter of the Sun is $1.39X10^6$km. Determine how close your result was. To do this,
$$\%error = \frac{(Actual\ diameter\ of\ the\ sun) - (measured\ diameter\ of\ the\ Sun)}{Actual\ diameter\ of\ the\ Sun} \times 100$$

Use the equation above to determine the %error of your measurement. Show all work and units.

Error: __________________

8. Write a few sentences about your results. Are the results close? What sources of errors can you think of? What can you do to make this experiment more accurate?

____

____

____

____

____

____

Name ____

Annual sun spot data

Plot the sunspot data. Below is a table of the average number of sunspots observed over the course of a year. It is obtained by a simple average of daily total sunspot number over all the days of the year. http://www.sidc.be/silso/datafiles

year	# sunspots	Year	# sunspots	Year	# sunspots	Year	# sunspots
1970	148.0	1984	60.5	1998	88.3	2012	84.5
1971	94.4	1985	20.6	1999	136.3	2013	94.0
1972	97.6	1986	14.8	2000	173.9	2014	113.3
1973	54.1	1987	33.9	2001	170.4	2015	69.7
1974	49.2	1988	123.0	2002	163.6	2016	39.8
1975	22.5	1989	211.1	2003	99.3	2017	21.7
1976	18.4	1990	191.8	2004	65.3	2018	7.0
1977	39.3	1991	203.3	2005	45.8	2019	3.6
1978	131.0	1992	133.3	2006	24.7		
1979	220.1	1993	76.1	2007	12.6		
1980	218.9	1994	44.9	2008	4.2		
1981	198.9	1995	25.1	2009	4.8		
1982	164.4	1996	11.6	2010	24.9		
1983	91.0	1997	28.9	2011	80.8		

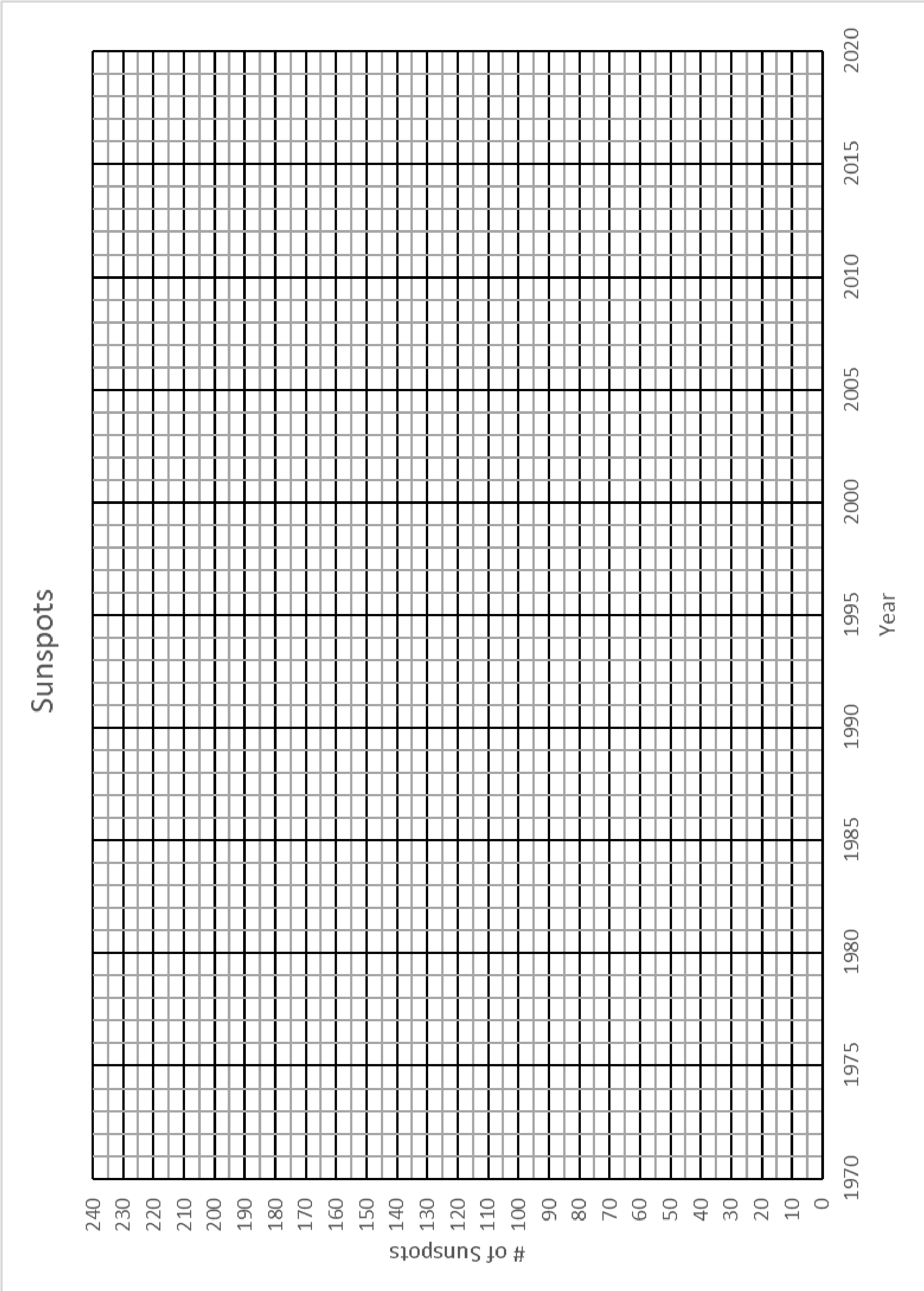
Use the chart on the next page to plot the date and the number of sunspots. Connect the dots to make a line graph. Circle the sunspot maximums and minimums on your graph.

1. List all the years that are maximum sunspot and minimum sunspots.

2. Find intervals between consecutive max and consecutive min (years between max to max, and years between min to min). Do you notice a pattern? Approximately when will be the next solar max & min?

____

Name ____


Sunspots
Year
# of Sunspots
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240

Distance Measurements

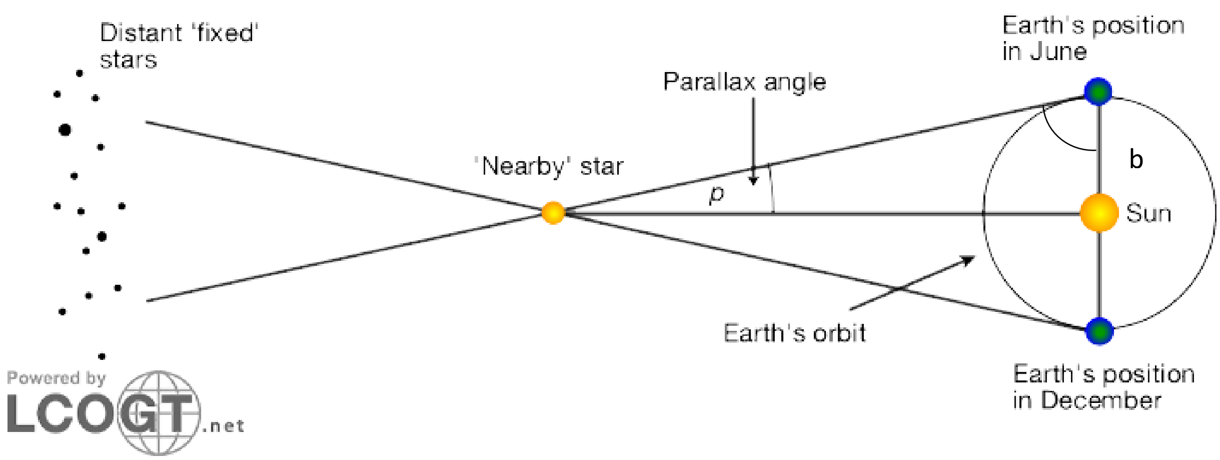
Have you ever wondered how scientists look at stars and determine how far away they are? For close objects, such our Moon, radar can be used. For further objects, we need to become a little more creative. In this lab, we will explore 4 main ways to determine distance to celestial objects: the parallax, main sequence fitting, cepheid variables, and type 1a supernova.

Parallax

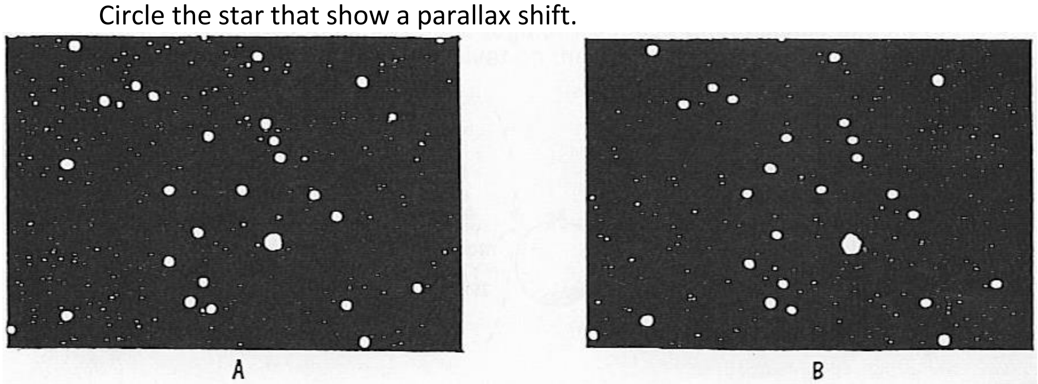
Stretch your arm out and hold up your index finger. Close or cover your right eye and look at your finger. Then, without moving your finger, close or cover your left eye and look at your finger again. Notice that the finger shifts relative to the background. This shift occurs because your eyes are separated by about 6 cm. If we can determine the angle of the shift, by knowing the separation of our eyes we can determine the distance to our finger.

We can apply the same concept to stars. Some stars are closer to us than others. The stars that are far away act as background stars. If we observe the stars from different locations, we can see the nearby stars shift relative to the background.

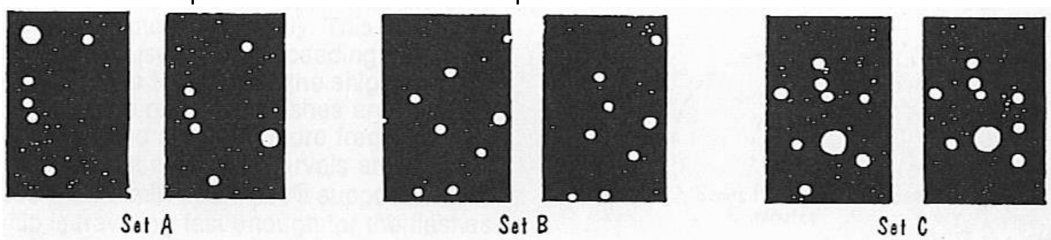
The figure below shows the schematics of the parallax. We can see here that $\tan p = \frac{b}{d}$, where p is the parallax angle in arcseconds, d is the distance from the Sun to the star, and b is 1AU. In practice, p is so small that we can use a small angle approximation to say $p = \frac{1}{d}$. d is measured in parsec, where 1 parsec results from when p = 1 arcsec. 1 pc = 3.26 LY.



1. The photographs below show the same section of the evening sky taken at a 6-month interval. Circle the star that show a parallax shift.



2. Each sets of the photographs below are all taken at 6-months intervals. Circle the stars that show a parallax shift in each set of photos.



3. Use a ruler and measure the linear amount of shift in mm.

Set A _______________ mm Set B _______________ mm Set C _______________ mm

4. Which set of photographs indicate the closest star? Which is the most distant? Explain.

Distance to the Moon

If we observe the Moon simultaneously from different locations on the Earth, it will be in different parts of the sky with respect to the background stars, because the Moon is much closer to the Earth than the stars are. We will use this parallax to calculate the distance to the Moon.

1. Open Starry Night. Make sure that you are in Los Angeles. Stop the time flow. Set the date to 2010, Aug 26. This was when the Moon was located near the Celestial equator, as well as being a large Moon phase which suits our purpose. Set the time to about 1AM.
2. From the "Options" tab to the left, click on "guides". Expand the "Alt-Az Guides" and click on Meridian. The Meridian should pop up on screen. Still in the "Options" tab, go to "Solar System". Hover your curser over "Planets-Moon", then click on the "Planets-Moons Options" box that pop up. In the options, *uncheck* the "Enlarge Moon size at large FOVs" option. This will make the Moon smaller for accurate measuring.
3. Find the Moon. Set the time flow rate to minutes or hours, and go backwards or forwards in time so that the Moon is on or close to the meridian.
4. Zoom in to the Moon to about 48^0X26^0 to see it more clearly. Look for a star that is also *close to the meridian*. This is so that we only have to consider one direction in angular separation. Hover your curser over it to obtain the name. This will be your background reference star. Write down the name for your records.

Reference Star ___________________________

5. Find the angular separation between your reference star and the center of the Moon. Record this in the table below.

	Angular separation		Angular separation
Los Angeles		Latitude 0°	

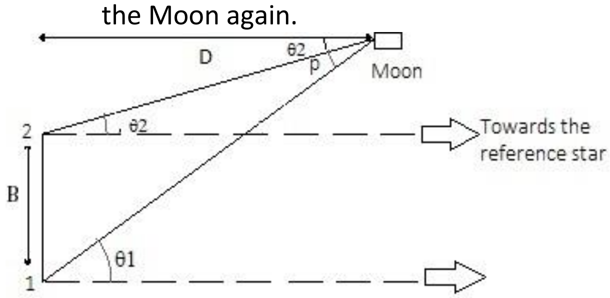
6. We will now observe the same Moon from another location on Earth. Keep the time and date the same. Open the "Viewing Location" option, choose "Latitude/Longitude". Enter "0" for Latitude, and leave everything the same. We are keeping the longitude the same so that we have to consider only one direction of the angular separation. What part on the Earth will this take you to (North Pole, south pole, etc)?

____

7. At this new location, find the Moon again. Since we did not change the time, the Moon should be still be near the meridian. Earlier, it was mentioned that the Moon is located near the celestial equator. In what direction will you find the Moon?

____

8. Find your reference star. Measure the angular separation between your star and the center of the Moon again.



This figure shows the schematics of what you are observing on starry night (same thing as you have been doing outside and the asteroid). θ1 and θ2 are the angular separation between the Moon and the star at the two different locations. Then $p = |\theta_1 - \theta_2|$. Subtract the smaller one from the larger one. Remember to convert arc minutes and arc seconds to degrees. Write your answer in degrees. Show work and units.

P=___________________________________

In order to find the distance to the Moon, we use our familiar equation $D = 57.3 \times \frac{B}{p}$ (small angle approximation this time!). B is the distance between the two observation locations.

9. Use this equation to find the distance to the Moon. The distance between Los Angeles and Latitude 0 is 3732.95 km. This is the straight-line distance between to two locations; not the distance along the surface of the Earth. Show your work and units and record your answer in km, in scientific notation.

D ____________________

10. Compare this to the actual distance to the Moon, which is $338.4 \text{X} 10^3$ km from Earth. Was it a good match? Why or why not?

Main sequence fitting

As you can imagine, using the stellar parallax is prone to large errors, and cannot be used for stars with large distances. For distant stars, we use Distance Modulus. For any star, its apparent magnitude and absolute magnitude are related to its distance by

$$5\log_{10} D - 5 = m - M$$

Where D is the distance to the star in parsec, m is the apparent magnitude, and M is the absolute magnitude. This is called the Distance Modulus. The trick is usually to find the absolute magnitude. One way to do this is to use the Main Sequence Fitting. Star clusters can include hundreds of thousands of stars. We can consider all of them to be the same distance from the Earth. Furthermore, main sequence stars on a H-R Diagram are identical for any star clusters. This means that H-R Diagrams from any star cluster will show the same absolute magnitude. Therefore, if we have a H-R Diagram from a known cluster (we do) we can compare the apparent magnitude of our cluster of interest, and calculate the distance.

1. Open a browser and go to https://astro.unl.edu/naap/distance/animations/clusterFittingExplorer.html

Here you will see a H-R Diagram with a main sequence of a cluster whose properties are well known.

2. In the Cluster Selection Panel, choose the Pleiades cluster. The Pleiades data are then added in apparent magnitude in blue.
3. Grab the data and drag it until the two main sequences are best overlapped.
4. Check "show horizontal bar" which will automate the process of determining the offset between the m and M axes.
5. Read the values for M and m, and insert it in the appropriate box. This will automatically calculate m-M below. Read the value for d and record here. Write the appropriate units.

m _________________ M ________________ d ___________________

6. Repeat for Hyades cluster and Pleiades. Take care when figuring out where their main sequence lines are!

	m	M	D
Hyades			
Pleiades			

7. Find the actual distance to the clusters (P601, P455). 1pc = 3.26LY. Are they a good fit?

Cluster	Actual Distance	Measured distance	Comment
Hyades			
Pleiades			

Cepheid Variables

Cepheid variables are red giant stars that pulsate in luminosity periodically. Its luminosity is so great that we can observe it in another galaxy. In fact, scientists first discovered the existence of other galaxies using Cepheid Variables. The pulsation period and absolute magnitude are strongly correlated and well-studied. This means that any cepheid variable with the same pulsation period will have the same absolute magnitude. Therefore, by measuring the apparent magnitude and the period, we may use the distance modulus to find the distance.

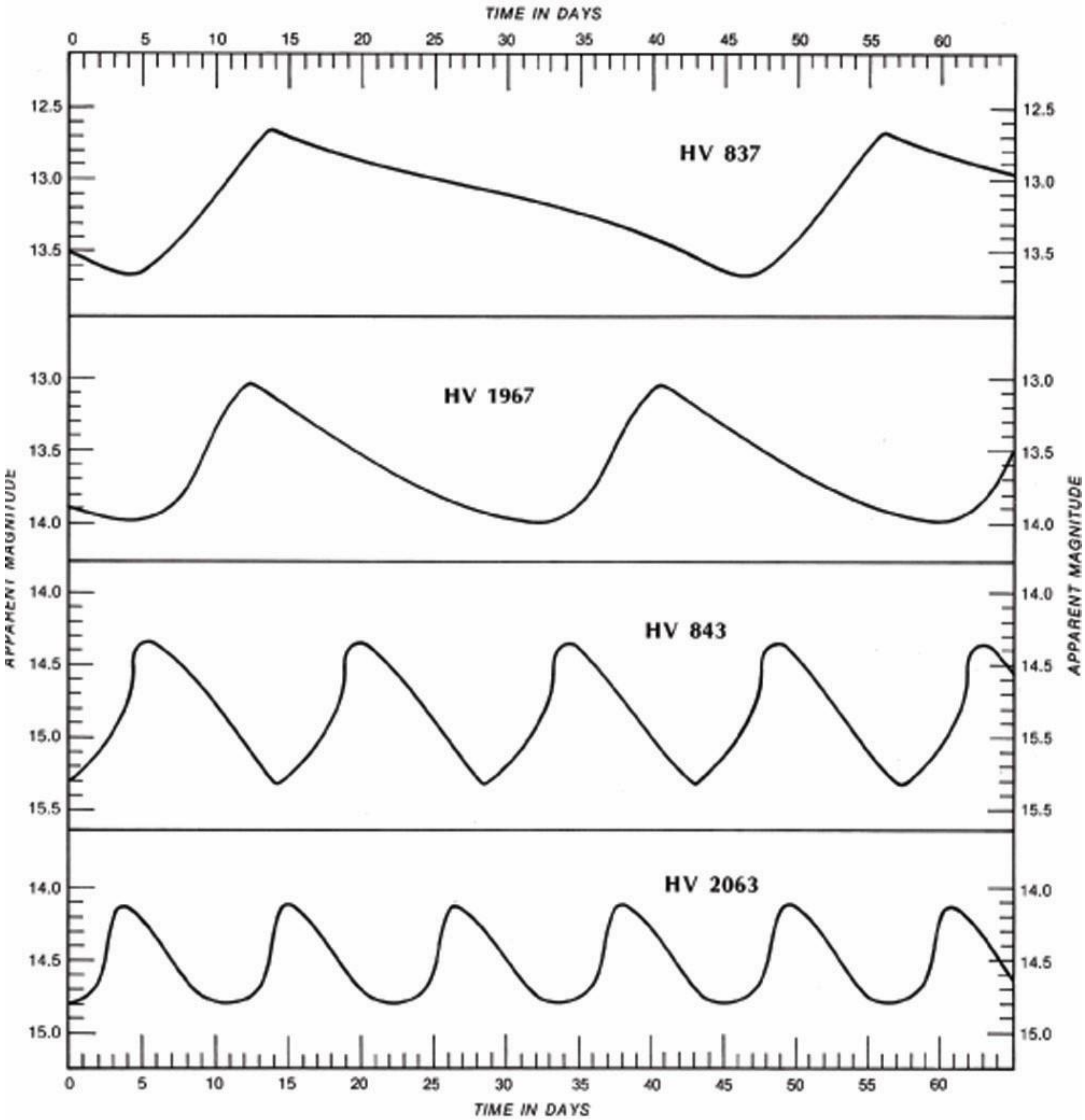
First, we will plot the absolute magnitude and period for cepheid variables that are already known. The table below is a 1918 study by Harlow Shapley. It is a list of logP and absolute magnitude calibrated from known Cepheid Variables

Shapley's Period-Luminosity Curve			
Log P	M	LogP	M
0.0	-0.4	1.0	-2.9
0.2	-0.8	1.2	-3.6
0.4	-1.2	1.4	-4.4
0.6	-1.6	1.6	-5.1
0.8	-2.2	1.8	-5.8

1. Plot Shapley's P-L curve on the graphing paper on the next page. Draw a straight line that best fits the data. The line will not go through all the data, but probably will have equal numbers of data points above and below the fit line.

The plot below is taken from Cepheid variables in a small magellanic cloud (SMC, a small galaxy).

2. For each of the stars read the pulsation period to the first decimal point. Then take the logarithm of the period. If your calculator does not have this function notify the instructor. Record in table.


TIME IN DAYS
HV 837
HV 1967
HV 843
HV 2063
APPARENT MAGNITUDE
APPARENT MAGNITUDE
TIME IN DAYS

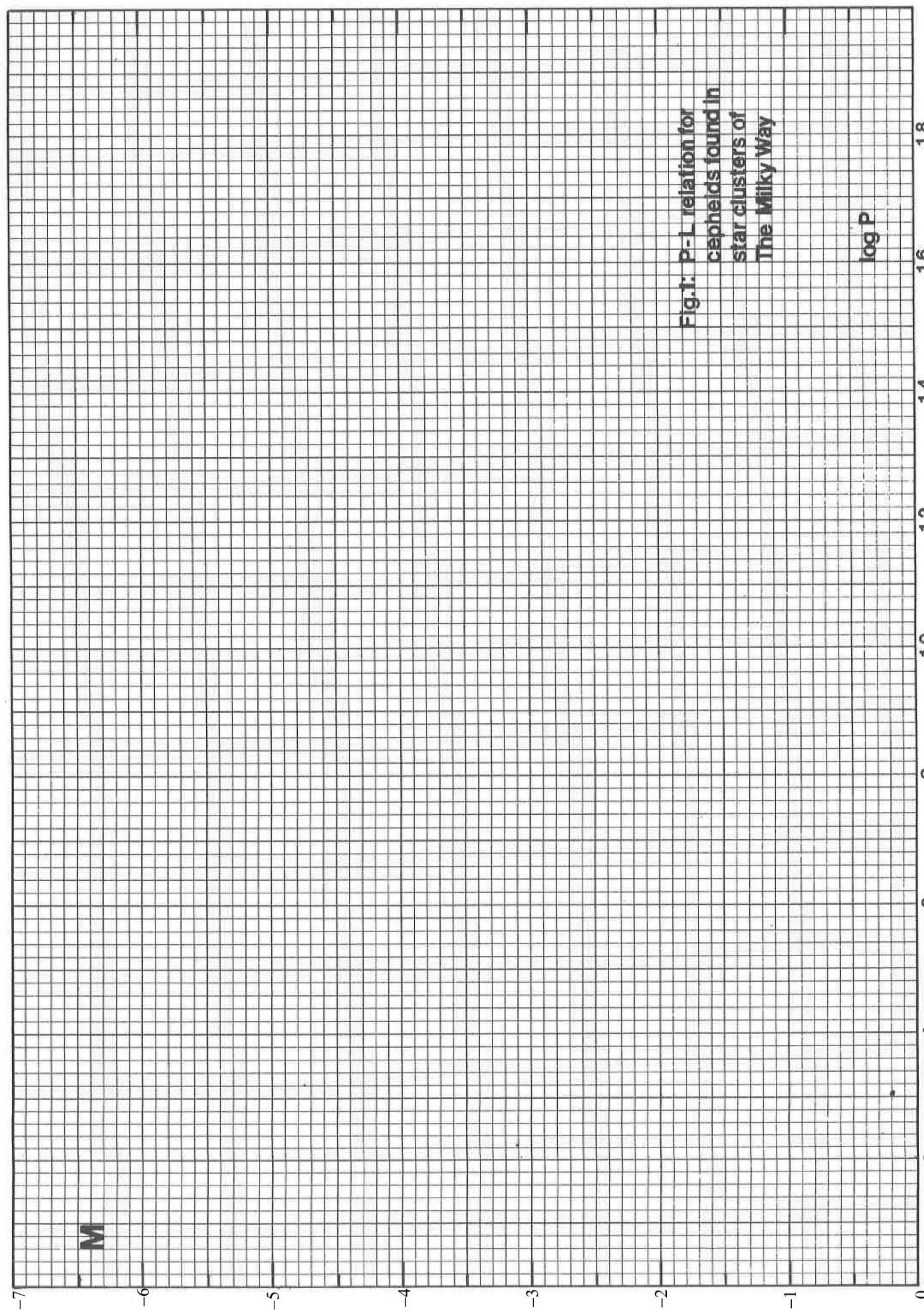


Fig.1: P-L relation for cepheids found in star clusters of The Milky Way
log P
M
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
0
−1
−2
−3
−4
−5
−6
−7

Star	P	logP	Absolute Magnitude	Average Apparent Magnitude
HV837				
HV1967				
HV843				
HV2063				

3. Take each value of Log P, and look at its position on the fit line on your graphing paper. The y-axis of that corresponding Log P will give you the absolute magnitude. Therefore, the resultant "y" is your absolute magnitude. Try to read accurately and record in the table.
4. Next read the average magnitude from the light curve of the four stars to the second decimal point. For greater accuracy, read equal numbers of magnitude value for each maximum peak and each minimum peak, and take the average. Use a ruler to line it up to the axis to read an accurate value.
5. Rearranging the equation for the distance modulus gives $D = 10 \times 10^{\frac{m-M}{5}}$ in parsecs. Calculate the distance to this SMC. Show work and units for one example.

____

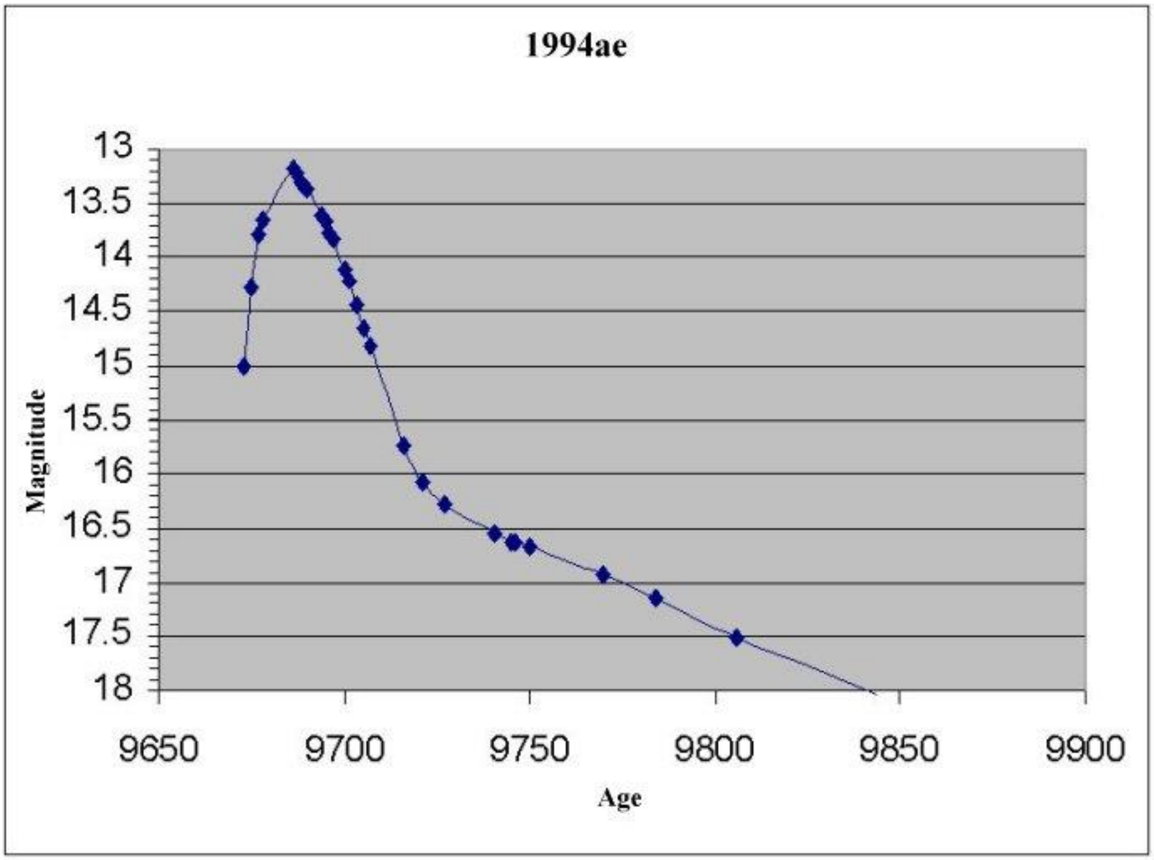
Star	Distance (pc)	Star	Distance (pc)
HV837		HV843	
HV1967		HV2063	

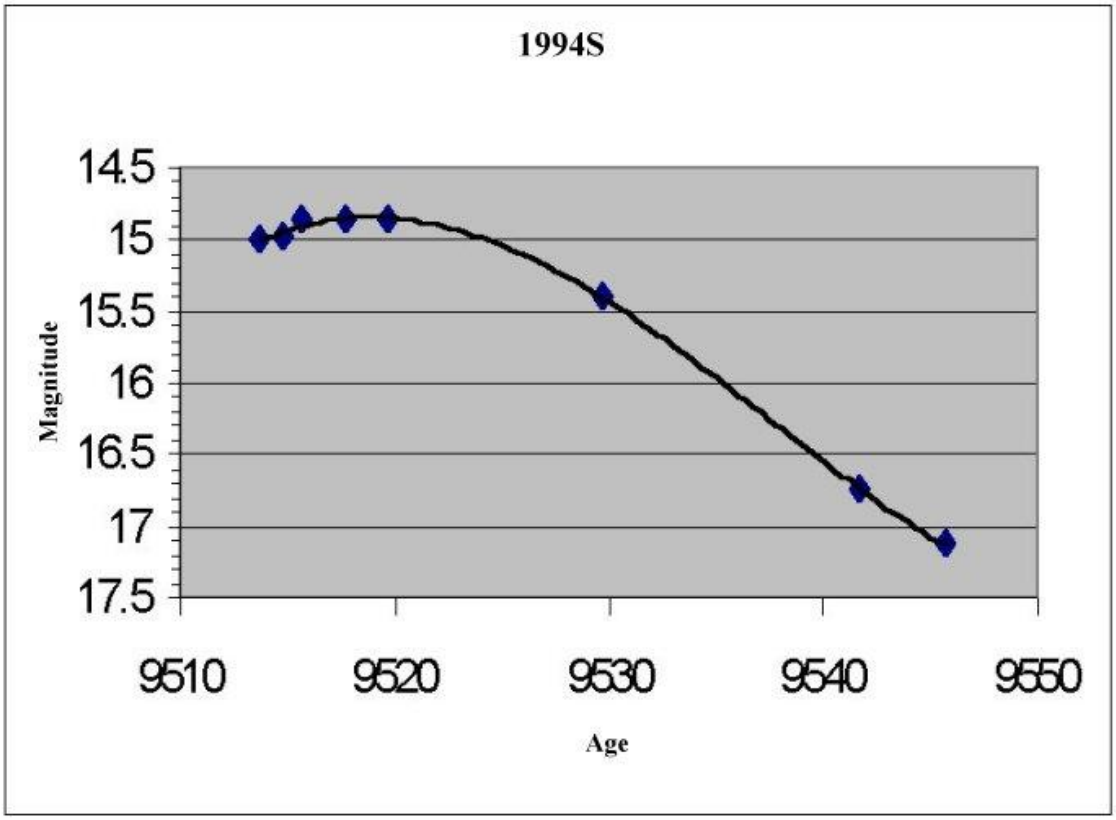
6. Compare your result with the actual distance to this galaxy (P. 607)

Type Ia Supernovae

Type 1a Supernovae are one of the most energetic events in the universe. They can be observed from the furthest part of the universe. This type of supernovae all occur in the same way, so they are standard candles. This means that all type 1a supernovae have the same peak absolute magnitude. We can use their apparent magnitude to find the distance by using the distance modulus.

1. All of the following show a light-curve from a type 1a supernovae. For each light-curve, read the apparent magnitude of the peak and record on the table provided at the last page. Use a ruler for accurate reading.





2. Use the distance modulus equation to find the distance to each supernova. The absolute magnitude (M) of a type Ia supernova is -19.2. Show one example of work and units. Record your answer in Mpc (Mega par-sec)

Supernovae	Apparent magnitude	Distance (Mpc)
1994ae		
1994s		

B-V and age of stars

Filters Simulator Overview

Open a web browser and go to https://astro.unl.edu/naap/blackbody/animations/filters.html. The filters simulator allows one to observe light from various sources passing through multiple filters and the resulting light that passes through to some detector. An "optical bench" shows the source, slots for filters, and the detected light. The wavelengths of light involved range from 380 nm to 825 nm which more than encompass the range of wavelengths detected by the human eye.

The upper half of the simulator graphically displays the source-filter-detector process. A graph of intensity versus wavelength for the source is shown in the leftmost graph. The middle graph displays the combined filter transmittance – the percentage of light the filters allow to pass for each wavelength. The rightmost graph displays a graph of intensity versus wavelength for the light that actually gets through the filter and could travel on to some detector such as your eye or a CCD. Color swatches at the far left and right demonstrate the effective color of the source and detector profile respectively.

The lower portion of the simulator contains tools for controlling both the light source and the filter transmittance.

In the source panel perform the following actions to become familiar with it.

- Create a **blackbody** source distribution – the spectrum produced by a light bulb which is a continuous spectrum. Practice using the **temperature** and **peak height** controls to control the source spectrum.
- Create a **bell-shaped** spectrum. This distribution is symmetric about a peak wavelength. Practice using the peak **wavelength**, **spread**, and **peak height** controls to vary the source spectrum.
- Practice creating **piecewise linear** sources. In this mode the user has complete control over the shape of the spectrum as control points can be dragged to any value of intensity.
    - Additional control points are created whenever a piecewise segment is clicked at that location.
    - Control points may be deleted by holding down the Delete key and clicking them.
    - Control points can be dragged to any location as long as they don't pass the wavelength value of another control point.

In the filters panel perform the following actions to gain familiarity.

- Review the shapes of the preset filters (the B,V, and R filters) in the **filters list**. Clicking on them selects them and displays them in the graph in the filters panel.
- Click the **add** button below the **filters list**.
    - Rename the filter from the default ("filter 4").
    - Shape the piecewise linear function to something other than a flat line.
- Click the **add** button below the **filters list**.
    - Select **bell-shaped** from the **distribution type** pull down menu.
    - Alter the features of the default and rename the filter.
    - If desired, click the **remove** button below the **filters list**. This removes the actively selected filter (can't remove the preset B,V, and R filters). Filters are not saved anywhere. Refreshing the flash file deletes the filters.

Filters Simulator Questions

- Use the piecewise linear mode of the source panel to create a “flat white light” source at *maximum intensity*. This source will have all wavelengths with equal intensity.
- Drag the V filter to a slot in the beam path (i.e. place them in the **filter rack** in the simulator above).
- Try the B and the R filter one at a time as well. Dragging a filter anywhere away from the **filter rack** will remove it from the beam path.

1. Sketch the graphs for the flat white light and V filter in the boxes below. What is the effective color of the detected distribution?

source distribution combined filter transmittance detected distribution

Detected Color ___________________________

2. With the flat white light source, what is the relationship between the filter transmittance and the detected distribution?

Add a new piecewise linear filter. Click on the line to add points, and adjust (create) the filter so that only large amounts of **green** light pass.

3. Use this green filter with the flat white light source and sketch the graphs below.

source distribution combined filter transmittance detected distribution

Remove your custom filter. Use the **blackbody** option in the *source panel* to create a blackbody spectrum that mimics white light.

4. What is the temperature of this blackbody you created? ______________________

Add a new piecewise linear filter to the **filter list**. Modify the new filter to create a 40% “neutral density filter”. That is, create a filter which allows approximately 40% of the light to pass through at all wavelengths. Set up the simulator so that light from the “blackbody white light” source passes through this filter.

5. Sketch the graphs created above in the boxes below. (This situation crudely approximates what sunglasses do on a bright summer day.)

source distribution | combined filter transmittance | detected distribution

6. Remove all filters in the filters rack. Place a B filter in the beam path with the flat white light source. Then add a second B filter and then a third. Describe and explain what happens when you add more than one of a specific filter.

7. Place a B filter in the beam path with the 40% neutral density filter. Then add a V filter into the beam path. Describe and explain what happens.

purple filter

8. Create a piecewise linear filter that when used with the flat white light source would allow red and blue wavelengths to pass and thus effectively allowing purple light to pass. Draw the filter in the box to the right. Label the axis.

- Remove all filters from the **filters rack**.
- Change the distribution source to a **blackbody source** peaked at green wavelengths (a temperature close to 5270 K). Notice the color. Change the temperature to 10,000 K and observe the color of the light source. Change the temperature to 3,000 K and observe the color.

9. Using observations from the above actions, explain why we don't observe "green stars" in nature, though there are indeed stars which emit more green light than other wavelengths.

Part I: An Analogy

Consider two cars, A and B. Car A is a two-door coupe. It gets 90 miles/gallon and has a 10-gallon tank. Car B is an SUV. It gets 2 miles/gallon and has a 60-gallon tank. Suppose both cars embark on a 200-mile journey together, side-by-side, each with a full tank of gas.

1. Which car holds more fuel? ______
2. Which car will run out of fuel first? You have to first calculate how many gallons of fuel each car will use during their 200-mile trip. Show work and units. Explain the apparent contradiction between your previous two answers.

As you know from experience, it is possible for something to hold more fuel but run out of that fuel faster. This idea applies directly to stars. Stars spend most of their lives on the main sequence where they convert the hydrogen in their cores into helium and energy. Stars that are more massive and have more hydrogen in their core will always run out of hydrogen fuel sooner than those that are less massive. This means that stars that contain more mass live shorter lives than those containing less mass. The "heavier" a star, the shorter the life span.

Part II: Lifetimes and Stellar Properties

Consider two main sequence stars; Proxima Centauri (the closest star to the Sun) and Vega (the star from the movie *Contact*). Proxima Centauri has a mass of 0.12 solar masses ($M_\odot$). Vega has a mass of 2.6 $M_\odot$.

3. Which star contains more hydrogen to fuse into helium? __________
4. Which star will run out of hydrogen first and thus leave the main sequence first? __________
5. Review your answer and explanation to 3 above. Using the same line of reasoning, which star do you think will be putting out more power (i.e., more energy per second / more luminous)? Explain your answer.

---

6. Generalize your results from 5 and 6 and complete the sentence below.

"For any given two stars, the star with the higher luminosity will have a shorter/longer lifetime" (circle one).

7. Consider two main sequence stars, the Sun and Vega. Vega is 51 times as luminous as the Sun. Which star will spend more time on the main sequence? How do you know?

Suppose an immortal astronomer were able to watch two stars being born together. The astronomer notices that star A leaves the main sequence after 4 billion years, becoming a red-giant afterward. Star B, however, leaves the main sequence after 10 billion years, becoming a red-giant afterward.

8. Which star was more luminous during its time on the main sequence?

____

9. Which star was more massive? __________

Recall from your lecture classes the relationship between the color of a star, its surface temperature, and its luminosity. Fill in the blanks in the following table so that the relationships are expressed clearly.

Color	Temperature (hotter or cooler)	Luminosity (higher or lower)
Bluer		
Redder		

What conclusion can you draw between the color of a star and its lifetime on the main sequence?

Color	Lifetime (longer or shorter)
Bluer	
Redder	

Part III: Clusters of Stars and the Color Index B – V

Astronomers describe stars by its colors. They do this by assigning a color index to a star. The color index is a quantitative measure of the color of a star, which in turn is a quantitative measure of the surface temperature of that star. The color index is a numerical value.

In order to eventually determine the ages of entire clusters, astronomers first have to determine the color index of many, many stars within those clusters. Therefore, let's briefly review what the color index is and what it tells us.

Astronomers can measure the apparent magnitudes of a star through various filters that are physically placed somewhere inside the telescope, usually just above the electronic detector (CCD). These filters allow only certain wavelengths of light (or colors) to pass through them. For example, a blue filter allows only the blue part of the spectrum from a star to pass through it; it reflects all other colors.

We will be using the B – V color index. This color index is calculated by taking the difference between the apparent magnitude of a star as observed through a blue filter (B) and the apparent magnitude of that star as observed through a "visual" filter (V), which is astronomy-talk for yellow. For example, let's say you took observations of a star through both blue and visual filters. You find that the apparent blue magnitude is 7.5, while the apparent visual magnitude is 7.2. The color index, or B-V value, would be 7.5-7.2 = 0.3.

1. If B-V is a large number, does is mean that the star appears more blue or red? Remember that brighter stars have smaller magnitude numbers.

____

2. Calculate the B-V values for the following main sequence stars:

Star	blue filter magnitude	visual filter magnitude	B-V
A	6.2	6.6	
B	11.2	11.2	
C	13.9	13.3	

3. Consider star A. Through which filter does star A appear brighter? __________
4. Do you think star A appears slightly more blue or slightly more red to our eyes? ___________
5. Of these three main sequence stars, A, B, and C, which do you think would register as the bluest? _____________
6. Which of these three stars will spend the least amount of time on the main sequence? Explain.

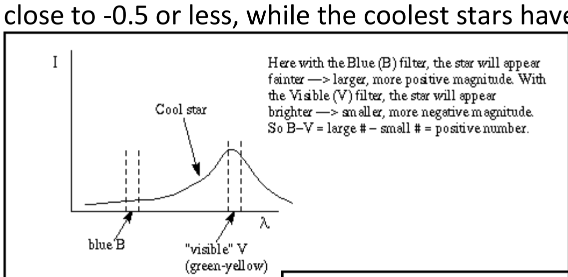
---

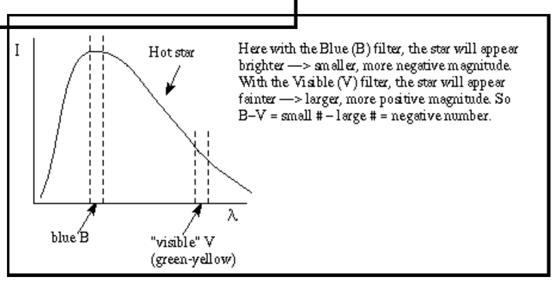
7. Generalize the results of this section.

Color Index	Lifetime on Main Sequence (longer or shorter)
Smaller number	
Larger number	

Summary

Hot stars appear bluer than cooler stars. Cooler stars appear redder than hotter stars. The "B-V color index" is a way of quantifying this using two different filters. The hottest stars have B-V color indices close to -0.5 or less, while the coolest stars have B-V color indices close to 2.0.

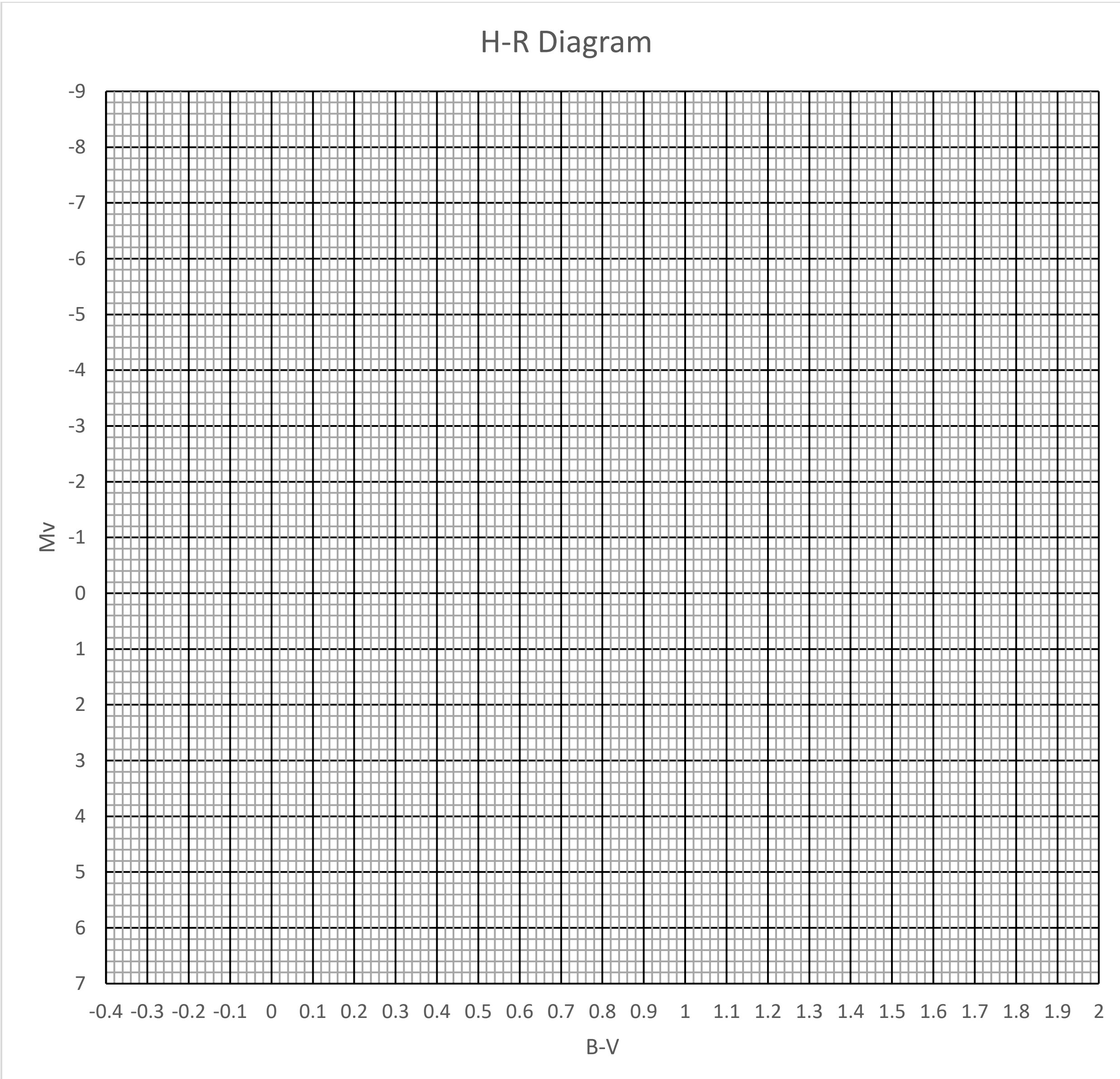




H-R Diagram using B-V

The table on the next page is a list of nearby stars with their B-V and Mv (absolute magnitude) values. Use these values to plot the chart on the following page. There is no need to label each star. When you are finished, circle the main sequence line on the plot.

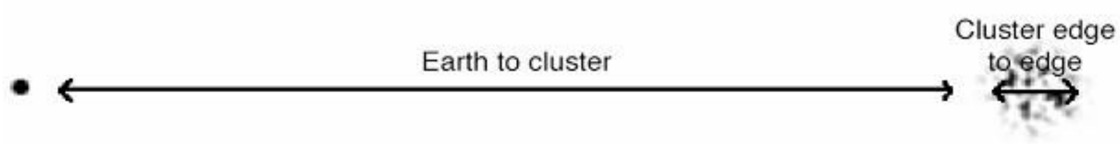
Name	B-V	Mv	Name	B-V	Mv
Sun	0.63	+4.82	gam Eri	1.59	-0.7
alp And	-0.11	-0.4	lam Tau A	-0.12	-1.3
bet Cas	0.34	2.0	alp Ret A	0.91	-0.9
Caph gam Peg	-0.23	-3.1	the^2 Tau	0.18	0.1
bet Hyi	0.62	3.8	eps Tau	1.01	0.2
alp Phe	1.09	0.7	alp Dor AB	-0.10	0.0
del And A	1.28	-0.3	alp Tau A	1.54	-0.3
eta Cas	1.17	-0.8	pi^3 Ori	0.45	3.9
bet Cet	1.02	0.3	iot Aur	1.53	-2.0
eta Cas A	0.57	4.7	eps Aur A	0.54	-7.8
gam Cas	-0.15	-4.7	eps Lep	1.46	-0.3
bet Phe AB	0.89	0.3	eta Aur	-0.18	-1.3
eta Cet	1.16	0.1	bet Eri	0.13	0.5
bet And	1.58	-1.6	mu Lep	-0.11	-0.2
del Cas	0.13	1.4	bet Ori A	-0.03	-8.1
gam Phe	1.57	-1.4	alp Aur AB	0.80	-0.4
alp Eri	-0.16	-1.3	eta Ori AB	-0.17	-3.8
tau Cet	0.72	5.8	gam Ori	-0.22	-3.9
alp Tri	0.49	2.6	bet Tau	-0.13	-1.5
eps Cas	-0.15	-2.4	bet Lep A	0.82	-2.1
bet Ari	0.13	1.8	del Ori A	-0.22	-5.8
alp Hyi	0.28	1.7	alp Lep	0.21	-5.1
gam And A	1.37	-1.8	bet Dor	0.84	-4.1
alp Ari	1.15	0.1	lam Ori A	-0.18	-5.8
bet Tri	0.14	1.3	iot Ori A	-0.24	-5.6
omi Cet A	1.42	-0.5	eps Ori	-0.19	-7.0
alp UMi A	0.60	-2.9	zet Tau	-0.19	-4.0
gam Cet AB	0.09	1.4	alp Col A	-0.12	-1.1
the Eri A	0.14	1.3	zet Ori A	-0.21	-6.2
alp Cet	1.64	-1.5	zet Lep	0.10	1.0
gam Per	0.70	0.3	kap Ori	-0.17	-7.0
rho Per	1.65	-2.6	bet Col	1.16	0.1
bet Per	-0.05	0.1	alp Ori	1.85	-7.2
alp Per	0.48	-5.1	bet Aur	0.03	0.3
del Per	-0.13	-2.2	the Aur AB	-0.08	0.0
del Eri	0.92	3.8	eta Gem	1.60	-0.7
eta Tau	-0.09	-1.5	zet CMa	-0.19	-1.6
gam Hyi	1.62	-1.1	bet CMa	-0.23	-4.9
zet Per A	0.12	-5.8	mu Gem	1.64	-1.1
eps Per A	-0.18	-4.2	alp Car	0.15	-2.5
tau Pup	1.20	0.1	gam Gem	0.00	0.7
eps CMa A	-0.21	-4.8	nu Pup	-0.11	-1.2
sig CMa	1.73	-4.0	eps Gem	1.40	-4.2
omi^2 CMa	-0.08	-6.3	xi Gem	0.43	-2.4
del CMa	0.68	-8.0	alp CMa A	0.00	1.4


H-R Diagram
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
Mv
-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2
B-V

Application Exercise: Determining Ages of Star Clusters Using Color Magnitude Diagrams

Clusters are groupings of stars that were all born at roughly the same time. When we speak of the age of a cluster, we are equivalently asking the ages of the stars. So why do we care how old clusters are? The age of a cluster can provide clues to the formation of galaxies and therefore the Universe. For example, stars in globular clusters appear to be the oldest in our galaxy. We can then infer that globular clusters were some of the first structures to evolve during the formation of our galaxy.

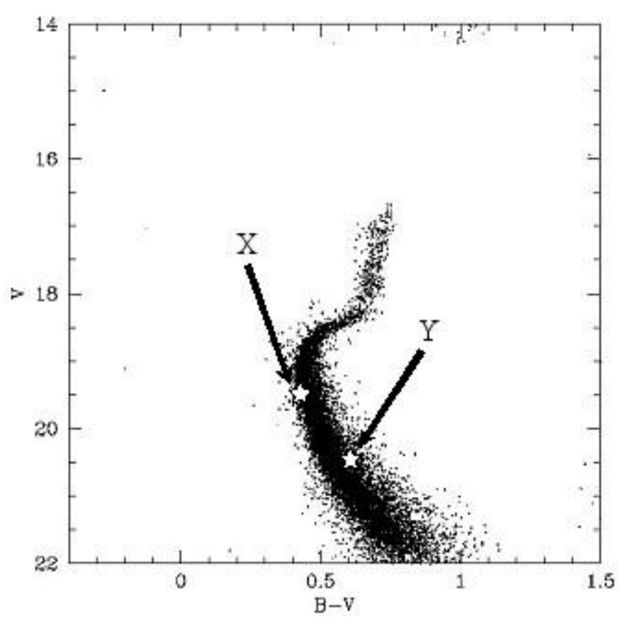
In a cluster of stars, we can use the apparent magnitude of its constituent stars as a relative measure of their luminosities. Since a cluster is localized to one relatively small volume of space, all of the stars within a cluster are roughly at the same distance from Earth. Because the stars are at roughly the same distance, differences in apparent magnitudes are due only to differences in the stars' luminosities. If a star in a cluster appears brighter to us compared to another star in the same cluster, then the brighter star must have a higher luminosity.



Finding the turn-off color-index of a star cluster

We are ready to turn to the object of interest: color-magnitude diagrams, or CMDs for short. A CMD, such as the one to the right, is a plot of all of the stars in a cluster, but with a very specific set of axes. Along the horizontal axis is the color-index of each star, and along the vertical axis is the apparent magnitude of each star. Note that the vertical axis is reversed: the values for apparent magnitude get smaller as you go up. Pause a moment to look at the CMD to make sure you note each of these features.

Every point on a CMD represents exactly one star. We can read off a star's B-V value by extending an imaginary vertical line down from the star to the horizontal axis. We can read off a star's apparent magnitude by extending an imaginary horizontal line left from the star toward the vertical axis.



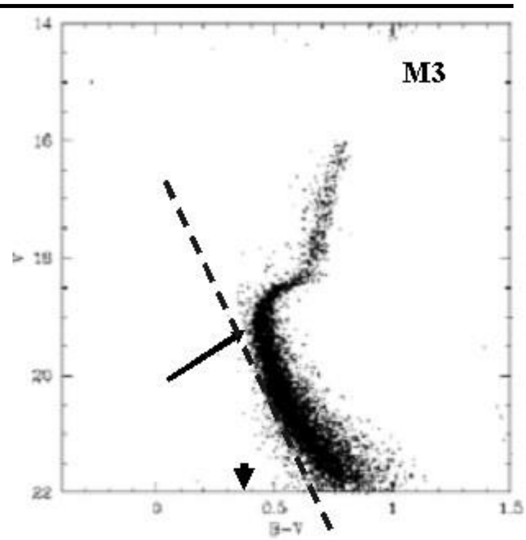
1. Using the CMD in this figure, estimate the B-V values of stars X and Y.

   Star X: ______ Star Y: ______

2. Which star is more luminous? ______

3. Notice that this chart plots visual magnitude, rather than absolute magnitude. Explain why this is valid for a star cluster.

4. Assuming both X and Y are on the main sequence and were born at the same time, which star will leave the main sequence first? Explain your answer.

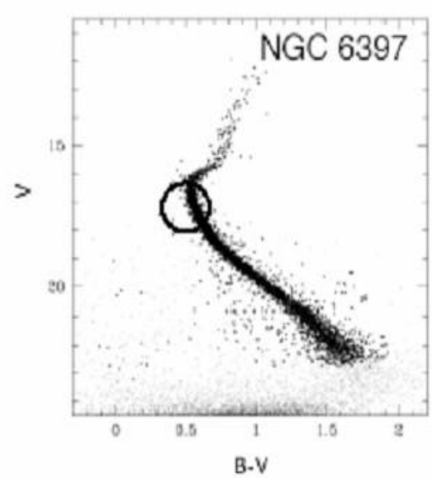


It's possible to visually identify the main sequence stars on a color-magnitude diagram. They lie within the long, relatively straight patch of stars that extends from the bottom right toward the top left of the CMD. Make sure this agrees with the labeled "Main sequence" on the CMD to the right, where we have drawn a heavy dashed line to represent the lower edge of the main sequence.

5. Put a box around the main sequence on the CMD to the right. Put a diamond around the group of stars that have left the main sequence and thus are no longer "on it."

The stars you put a diamond around have run out of hydrogen fuel in their cores. They have spent their lifetime on the main sequence and have "left it." The transition region between stars on the main sequence and those that are already off the main sequence is of importance to us. It is called the turn-off point or turn-off region. (The location of this point will vary from cluster to cluster, and will allow us to eventually determine the age of clusters.)

6. Circle the small region on the CMD shown above where stars are just beginning to "peel away" from the main sequence. Label this as "turn-off point". The B-V value corresponding to this turn-off point is called the B-V turn-off point. What is the B-V turn-off point for this cluster?



7. The approximate turn-off point for a different cluster, NGC 6397, has been circled for you. Draw a diagonal line that represents the main sequence stars. Estimate the B-V value for the turn-off point for this cluster.

B-V = ______

You should now have a good idea of what a CMD plots are and how to determine the B-V turn-off point. This method is something that many astronomers do in their careers today.

I. Estimating the ages of clusters

Let us re-focus our attention to individual stars for a moment, instead of entire clusters. So far, we know only that main sequence stars with a lower B-V value will spend less time on the main sequence. There is, however, a quantitative relationship between these two quantities.

Color Index (B-V)	-0.4	-0.2	0.2	0.5	0.7	1.0	1.6
Main Sequence Lifetime (years)	$<10^6$	$3X10^7$	$4X10^8$	$4X10^9$	$1X10^{10}$	$6X10^{10}$	$>10^{11}$

Take a look at the main sequence lifetime for a star of color-index -0.2. The stated lifetime, 3×10^7 years, is the time it will take a star, from when it first starts fusing hydrogen to helium in its core, to leave the main sequence. If a star of color-index -0.2 started its fusion this morning, it will leave the main sequence in 3×10^7 = 30,000,000 = 30 million years. If a star of color-index -0.2 started its fusion 10 million years ago, it would leave the main sequence in 20 million years. If the star started its fusion 30 million years ago, it would just now be leaving the main sequence.

1. An astronomer measures the visual magnitude of a main sequence star called Keid (located in the southern constellation of Eridanus) through a blue filter to be 5.4 and the corresponding visual apparent magnitude value to be 4.4. Once its core fusion starts, how long would it take Keid to leave the main sequence?

____

The same astronomer measures the color-index of a different star, Altair (located in the northern constellation of Aquila), to be 0.2. This astronomer knows that Altair is about 3×10^8 = 300,000,000 years old.

2. Approximately how many years from now will the star leave the main sequence?

   ____

   Going back to clusters, recall that all the stars in a given cluster were born at the same time. If we were able to determine the age of one of the stars in that cluster, we would know how old all of the stars are. That star needs to be at or close to the turn-off point of the main sequence.

3. Look at the stars at the turn-off point in NGC 6397.
   a How long do stars with this B-V live on the main sequence? _________________
   b Are the stars at the turn-off point leaving the main sequence? Yes/No
   c Using this information, how old are the stars at the turnoff point?__________
   d How old are all of the stars in this cluster?__________
   e How old is NGC 6397?__________

You have just determined the age of NGC 6397 using only the B-V value of the turn-off point.

II. Following ONE cluster through time

Stars within a cluster get older, which mean the cluster gets older as well. If the B-V turn-off point can tell us the age of a cluster, then the B-V of the turn-off of a given cluster must change through time.

1. You probably determined previously that the age of NGC 6397 was around 4 billion years. In 6 billion years, the age of the cluster will be 10 billion = 1×10^{10} years old. What will the B – V turn-off value be for NGC 6397 in 6 billion years?

____

2. Generalize your result from question 1. Suppose we you were able to witness the entire evolution of a cluster of birth. Describe how the B-V turn-off would change as time progressed.

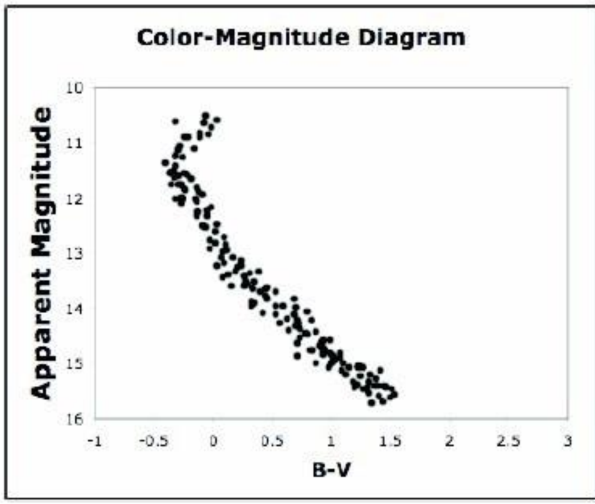


Figure A

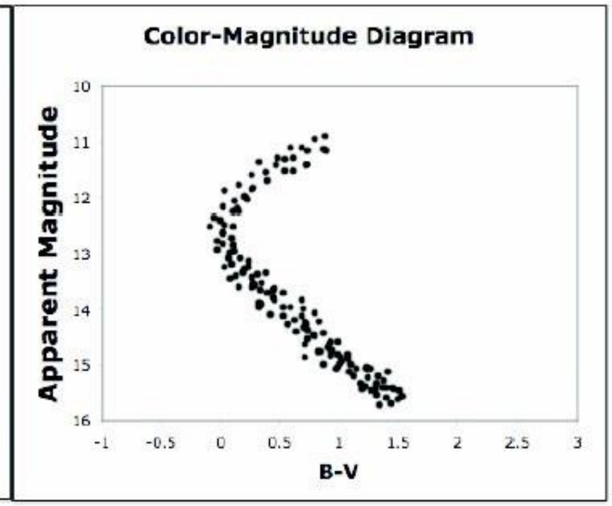


Figure B

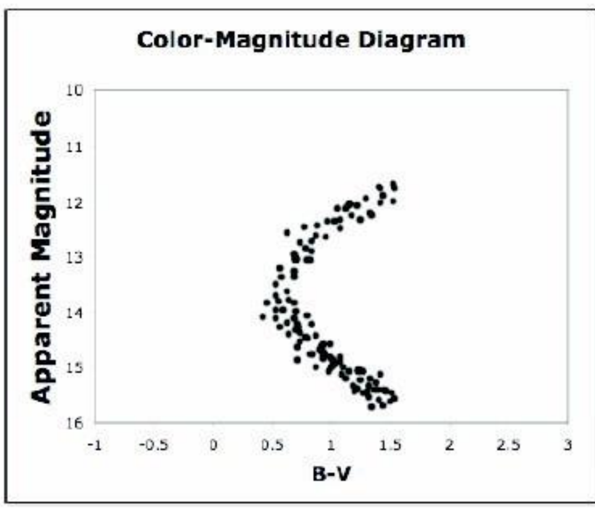


Figure C

3. Examine the three "simulated" CMDs that are shown above. These CMDs all represent the same cluster of stars, but at different ages. For each "snapshot in time" of the cluster, circle the turn-off point and measure the B-V turn-off value. Rank the plots of the CMDs in terms of age of the cluster when the data was taken, from when the cluster was the youngest to when it was the oldest.

Cluster is youngest ________ ________ ________ Oldest

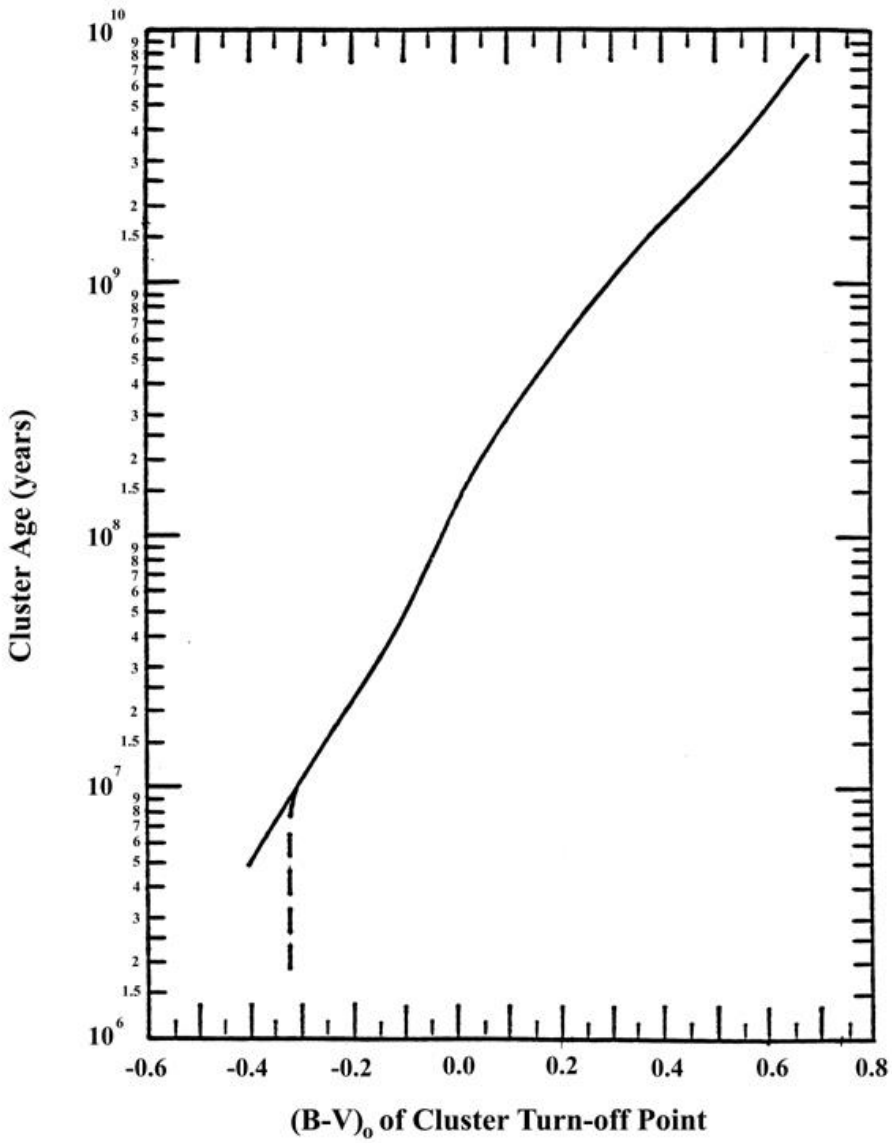
4. Explain the logic you used.

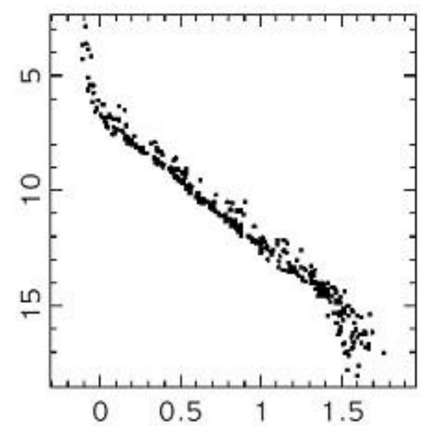
5. Instead of the three CMDs representing the same cluster as observed at different ages, suppose they are representing different clusters that we observe in one night. Rank the CMDs in terms of the ages of the different clusters shown, from youngest to oldest.

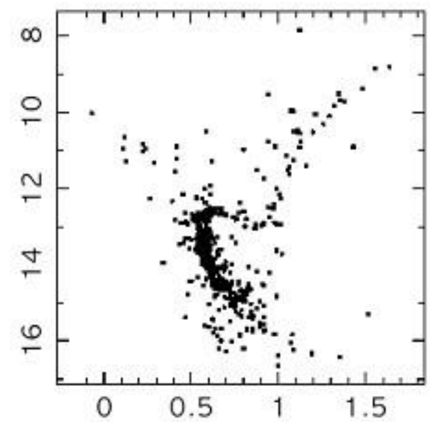
Youngest cluster ______ _______ _______ Oldest

6. Explain the logic you used.

7. Below is a plot of cluster age and B-V turn off point. Use this to determine the B-V value of the turn-off and the age of each of the four open clusters in the following page.

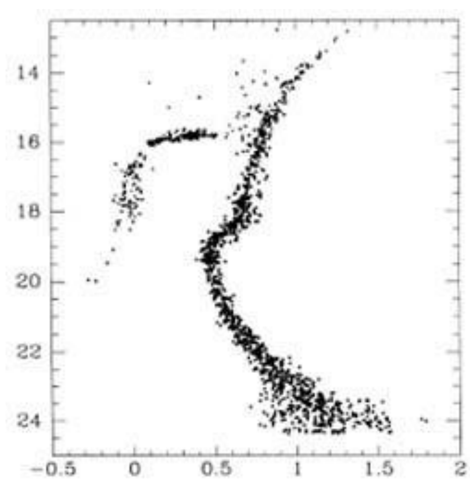


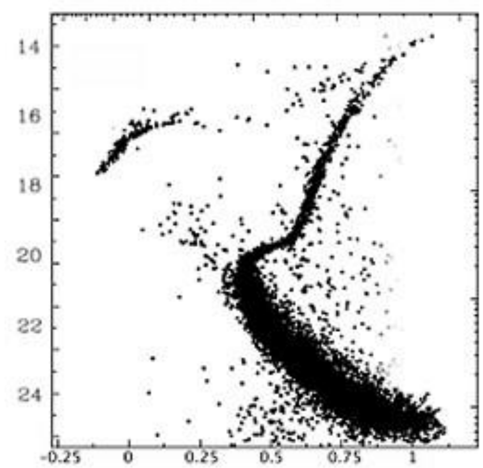




Turn Off _____   Pleiades age: __________________   Turn Off _____   M 67 age: _________________

8. Determine the B-V value of the turn-off and the age of each of the following globular clusters.





Turn Off _____   M 15 age: __________________ Turn Off _____   M 55 age: _________________

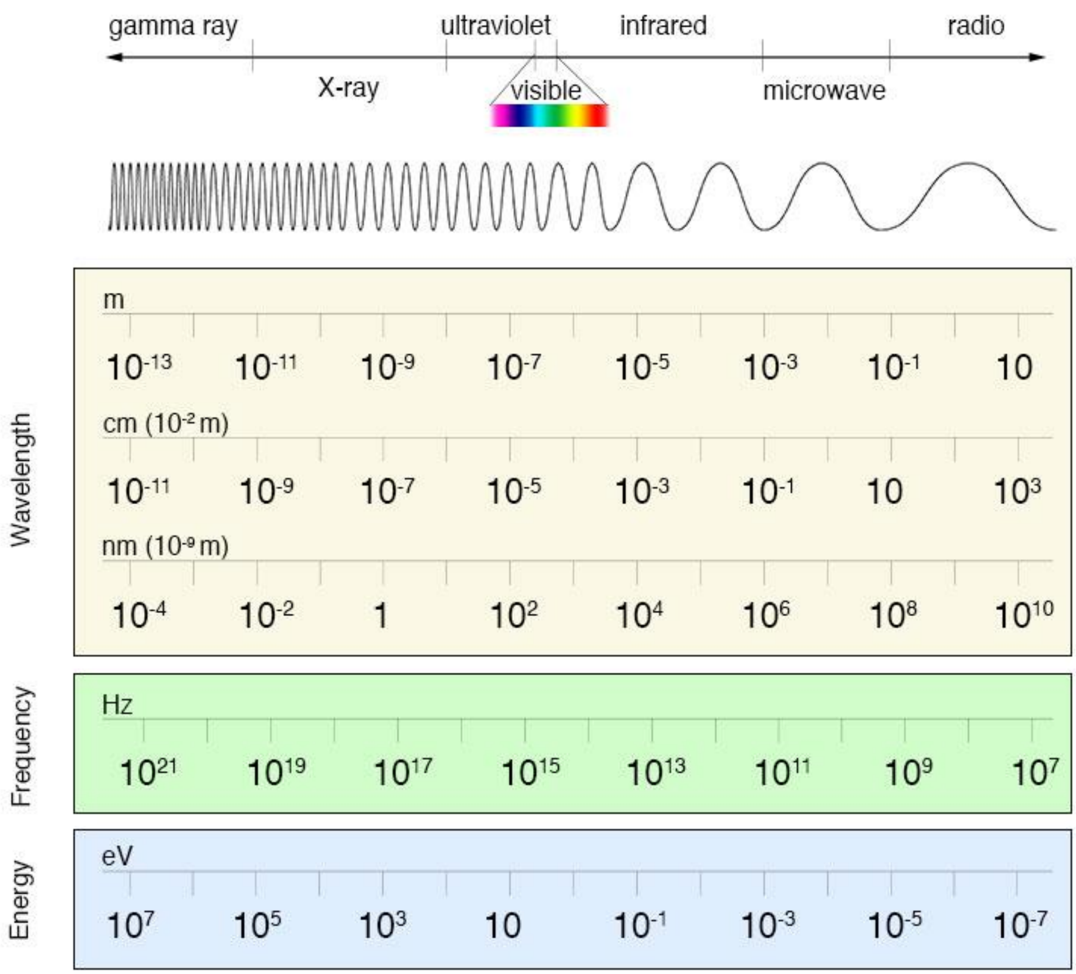
9. In your own words, explain why a color-magnitude diagram allows us to determine the age of a cluster. This should not be a step-by-step how-to. Rather, your response should incorporate ideas such as distance, luminosity, lifetime of stars, how clusters are formed, and similar concepts.

Spectroscopy

Properties of Light

Light has wavelength, frequency, and energy.

We study astronomy by observing light that enters our eyes from the universe. Light is a wave, so first let's study the properties of a wave. Among the many characteristics of waves, you need to know three of them. They are wavelength, frequency, and energy.



Look at the picture above. Wavelength is the distance from peak to peak. Frequency is the number of peaks observed each second. Energy is directly proportional to the frequency. For questions 1-3, circle either "larger" or "smaller".

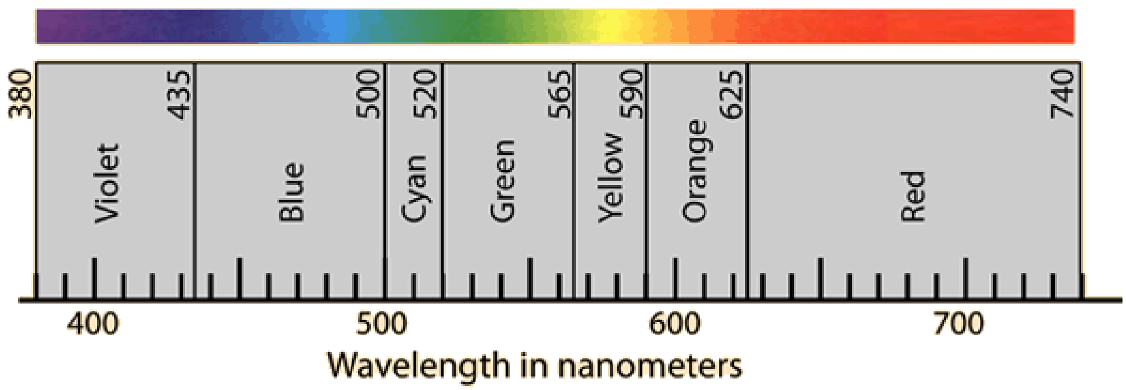
1. As you observe from the left to the right, is the wavelength becoming larger or smaller?
2. As you observe from the left to the right, is the frequency becoming larger or smaller?
3. As you observe from the left to the right, is the energy becoming larger or smaller?

Light can have all kind of wavelength/frequency/energy, but not randomly

Look at the picture above, and circle the appropriate choice.

4. Light with a short wavelength has high/low frequency, and high/low energy.
5. Light with low energy has long/short wavelength, and high/low frequency.

We see light in different colors because each light of different color has a different wavelength



6. Look at the figure above. It represents all the colors we can observe with our eyes. What is the color with the longest wavelength? Red/blue What is the color with the shortest wavelength? Red/blue. Approximately what wavelength does the color Green have? Include units. ___________________.
7. Knowing what you have learned from questions 4 &5, circle the appropriate choice in the following sentences. "red light has long/short wavelength, high/low frequency, and high/low energy". "blue light has long/short wavelength, high/low frequency, and high/low energy"

*In astronomy, "blue" doesn't mean literally blue. It means "short-wavelength part of the spectrum" or "long-wavelength part of the spectrum. Technically violet has the shortest wavelength, but astronomers say blue to mean short wavelength.

Atomic Structure

Now let us see how this is related to atoms.

8. First, we need to understand the atomic structure. Go to https://edu.rsc.org/download?ac=501330. Click on Atom. On the left side, you should see two circles with and X, and three buckets underneath labeled "Protons", "Neutrons", and "Electrons". Click and drag on one of the small red balls from the Proton bucket to the X. Next click and drag one of the little blue Electrons towards the blue line, and release. You have created a hydrogen atom! Draw what you have created in the box bellow. Include the blue lines. Label the proton and the electron.

This is called the Bohr model of the Hydrogen atom. *disclaimer* This is not exactly how an atom looks. In reality, electrons exist in a “probability cloud”. If you click on “cloud” at the middle, you can see how this looks. However, we still use the Bohr model since it is easier to understand.

Electrons can have only certain energies. Open Class Action. Go to “All Modules” -> “Light&Spectra”. From the bottom menu, select “Animations” -> “Hydrogen Atom Simulator (NAAP)”.

The proton is on the very left side of the window and the electron is just outside of it. Notice the white concentric circles. Each circle represents different energies that an electron can have. You can think of the circles as elevator stops. You can ride an elevator and move from one floor to another, but you cannot stop between floors. Similarly, electrons can have certain energies, but not anything in between. *If an electron exists in one of the circles, it contains that exact amount of energy*.

9. Look at the main window on the top left. The energy level for each circle is listed below in the lowest of the three scale bars. Look at the energy of the circle closest to the proton, then at the circles that are the furthest from the proton. If an electron exists at the orbit *furthest* from the proton, does it have a high energy or low energy? Circle “high” or “low”.
10. Currently, does the electron have the lowest energy possible? Or the highest energy possible? Circle “lowest” or “highest”.

Takeaway: The energy level from closest to the proton to the furthest from the proton are named “n=1, n=2, n=3…” and so on. n=1 is also called the “ground energy level”.

For example, if the electron moves from the energy level closest to the proton to the fourth energy level, we say “the electron transitioned from n=1 to n=4.” Or “the electron at ground level transitioned to n=4.)

Interaction between Atoms and Light

To gain energy, electrons need to gain energy from an outside source

At the bottom, below the slider, there are many buttons with letters on them. The letters mean something, but we will not get into that. Click on the button that says "L_α", and observe what happens. It happens quickly, so click on it as many times as needed to observe everything.

11. What do see first enter from the right side of the screen? What color is it?

____

Electrons absorb specific energies that take them to a different energy level.

12. What happens to the light after it collides with the electron? What happens to the energy electron after the light collides with it? Does the electron stay at the same energy level? If not, which energy level does it move to?

____

____

____

Takeaway: That was light! As we learned earlier, light contains energy. The light collides with the electron and the electron "absorbs" its energy.

Electrons like to stay at the lowest energy (ground level)

13. After the electron becomes excited (excite means to gain energy), does it stay excited? Does it change energy level? If so, to which energy level does it switch to? What happens as the electron change energy level?

____

____

____

____

Takeaway: Electrons do not like staying at high energy. They spontaneously drop down to the ground state. To drop lower energy level is to called "relax". Electrons need to release excess energy in order to relax. They do that by emitting the excess energy in the form of light! We are able to observe this light as different colors!

14. On the left bottom of the screen, click on the button "P_α". Describe what happens. Did the electron stay at the same energy level?

____

____

____

Takeaway: This time, the light that collided with the electron did not have enough energy. Electrons need to absorb the exact amount of energy required to jump to the higher energy level.

Energy levels/colors are unique to each atom

15. Click on the button "L_γ". Was the photon (light) absorbed or emitted? What color? To what energy level? After the electron was excited/relaxed, what happened to it? Did you see the same color of light? How many different colors of light was involved? What energy transitions occurred?

____

____

____

____

____

16. Look at the "Event Log" to the right. All absorption and emission events are logged. Complete the table. *You may not need all the rows, since there are more than one way an electron can return to lower energy. Record the event that you see on your screen.*

Event Tyepe	**Energy level transitioned**	**Energy Emitted/Absorbed (eV)**	**Color of light**
Absorption	n= ___________ to n = ___________		
Emission	n= ___________ to n = ___________		
Emission	n= ___________ to n = ___________		
Emission	n= ___________ to n = ___________		

17. Add the energies of the two emission events. Compare it to the absorption event. What do you notice?

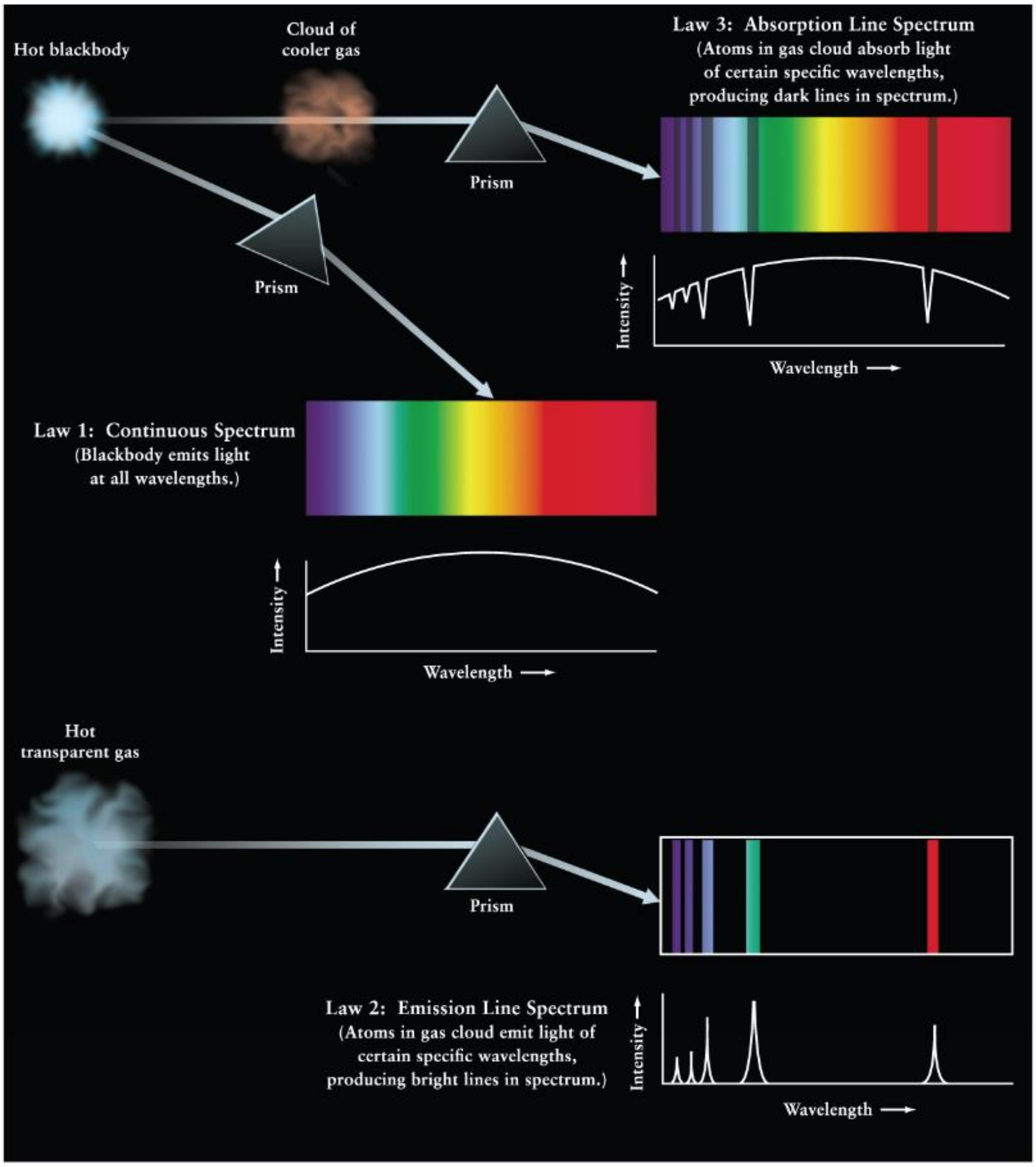
____

Takeaway: An electron absorbs a specific amount of energy to become excited. The electron will emit the exact same amount of energy in order to be relaxed again. It may take two or three steps to relax to ground level, but it will emit the same amount in total.

Viewing the Spectra

The energy transition and combination is unique to each different atom. For example, a hydrogen atom absorbs 10.2 eV to transition from n=1 to n=2. This value is different for a n=3 to n=5 transition, and is different for all atoms. Since each atom have unique electron energy combination, each atom has unique color signatures.

Continuous, emission, and absorption spectrum look different



Geller et al., *Universe*, 11e, © 2019 W. H. Freeman and Company

Spectroscopy is the study of light by separating it by its wavelength. Isaac Newton discovered that light is not made of a single color. If you pass light through a prism, the light will be separated by all the colors it is made of. For example, normal white light (daylight from the Sun) is actually composed of all the colors of the rainbow. Combined together, we see "white".

Look at the picture. A hot, dense gas will produce all the colors of the rainbow. This spectrum is called the "**Continuous Spectrum**". Electrons in hot, thin gas are constantly excited. However, remember that electrons like to be relaxed. They spontaneously drop energy level, and emit light as they do so. In this situation, we see bright lines of specific colors. This is called the "**Emission Line Spectrum**". When a hot, dense, gas emit all colors, and the colors pass through a cloud of cold gas, the low-energy atoms in the cloud absorb energy from the light to become excited. The left-over light exits the cold gas. What we observe look like a continuous spectrum, but with specific colors missing. This is called the "**Absorption Line Spectrum**". Remember this!

Under the same "Animations", select "Spectrum Explorer". This simulate light originating from various gas passed through a prism. The top window is the spectrum observed.

18. Make sure that at the very left, the choice is set to "continuous". In the plot below, draw the spectrum.

Type of spectrum: ______________________

400 700

19. In the choices towards the left under "Spectrum", set it to "emission". In the choices under "Elements", choose "Hydrogen". In the plot below, draw the spectrum.

Type of spectrum: __________________ Element: ________________________

400 700

20. Uncheck hydrogen, and click on "Helium". In the plot below, draw the spectrum.

Type of spectrum: __________________ Element: ________________________

400 700

21. Are the spectra from hydrogen and helium identical? Why or why not?

____

____

In the left under "Spectrum", choose "Absorption". At the bottom left under "Luminosity Class", choose "V". At the bottom right under "Spectral Type", slide the bar to "B5".

22. On the upper right under “Elements”, check “Hydrogen”. Make sure nothing else is turned on. In the plot below, draw the spectrum.

Type of spectrum: _________________ Element: _______________________

400 700

23. Uncheck hydrogen and check “Helium”. In the plot below, draw the spectrum.

Type of spectrum: _________________ Element: _______________________

400 700

24. Compare your drawing of the emission line spectrum and the absorption line spectrum of the hydrogen atom. Also compare the emission line spectrum and the absorption line spectrum of helium. What do you notice about the positions of the emission lines and absorption lines? Does it make sense?

____

____

____

____

____

____

Takeaway: The colors of the emission line spectrum and the missing colors of the absorption spectrum are unique to the atoms that make the hot, thin gas, and the cold gas respectively. But for each element, the lines involved with emission or absorption are the same; only different temperature and conditions. To summarize, from emission line spectrum, we can learn the composition of the hot, thin gas. From absorption line spectrum, we can learn the composition of the cold gas.

25. A star has a hot dense core. The temperature of a star’s surface is much cooler compared to the core. When we observe the star’s spectrum, do we observe a continuous, emission, or absorption line spectrum?

____

26. If absorption or emission, what information can the absorption/emission lines tell us about stars

____

____

Takeaway: Stars emit an absorption line spectrum! The hot inner part of the stars emit light, and the cooler surface absorb some colors. The absorption colors tell us the chemical composition of stars!

Hot, dense gas emit a blackbody spectrum

While still in the “Animations”, open “Blackbody Curves (NAAP)”.

27. In the box below, draw the graph that you see. Use the box as axis. Label the axis. On the upper right, you will see the temperature of this object. Record the temperature.

Takeaway: This plot is called the “**Blackbody Spectrum**”. Anything that produces this type of curve is a blackbody. Notice the curve is a smooth curve with no breaks. This curve shows all the colors of the rainbow in a continuous curve. **A blackbody curve is a continuous spectrum**.

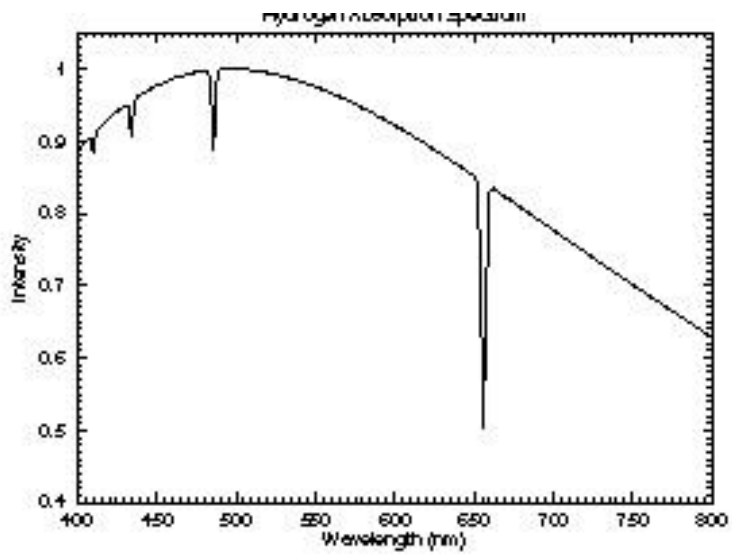
28. What is the title of the X-axis? ___________________ According to questions 6&7, is the left side red or blue? _______
29. What is the title of the Y-axis? __________ Look at the highest point of the curve. What color does the highest peak correspond to (look back to question 6)? ________________ When the peak is high, is it a high flux or a low flux? ____________

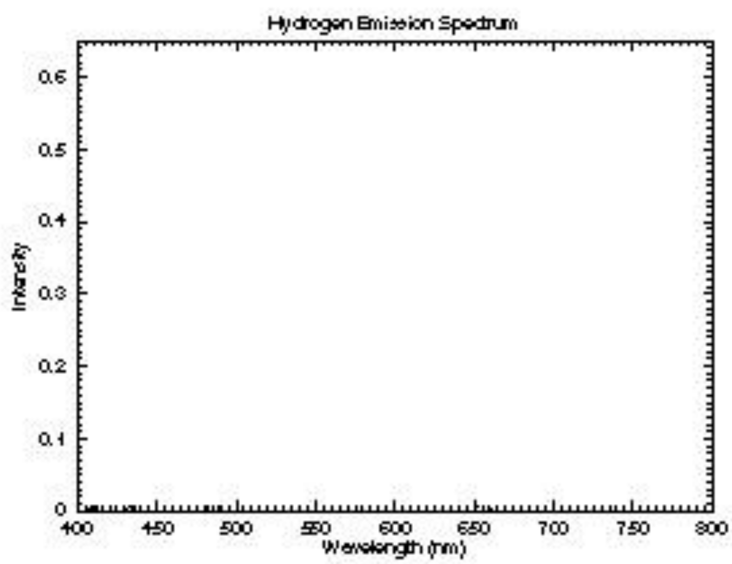
Takeaway: Flux means the number of photons received each second. A high peak means that there are many of the specific color of photons. A blackbody produces all the colors of the rainbow, but produces the most amount of light in a specific color. This is not information that is included in the simple continuous spectrum. The blackbody spectrum tells us how much of the color the blackbody object emits.

Absorption and Emission Spectrum can be shown in this plot too

Look at the picture on page 6 again. At the top, you can see the absorption spectrum in color. Underneath it, you can see the blackbody curve. The blackbody curve is not smooth, and has dips at the place where there are dark lines in the colored spectrum. This is the absorption line spectrum shown as a blackbody spectrum. At the very bottom of the picture, you can see the emission line spectrum in color. Beneath it, you can see the same emission line spectrum shown against the flux. When showing the flux, you can see that the curve is mostly flat except for the specific colors in spikes. The flat line show that there is no photons in that color, which is why the spectrum in color is mostly black.

30. In the figure bellow, the top spectrum shows an absorption spectrum from a hydrogen star. In the box at the bottom, draw the emission spectrum for a hot, thin, hydrogen gas.





The peak of the blackbody spectrum tells us the temperature of the object

31. Go back to the "Blackbody Curves" simulation. Make sure the curve shows 6000K. On the lower right, click the button "add curve". On the upper right, use the slide bar to make the temperature 10000K. In the box below, draw the curves. Pay attention to the height and the wavelengths of the peaks. Use the box as the axis. Label the axis. Indicate which curve is 6000K and 10000K.

32. In the middle right window, you should see the temperature, peak wavelength, and area under curve. Record the peak wavelength.

6000K Peak wavelength ____________ nm 10000K Peak Wavelength _____________ nm

Disclaimer This is a simulation of a perfect blackbody star. As we saw in question 25, a star produces an absorption line spectrum. This simulation shows a star's spectrum without the absorption lines. If a star was a perfect blackbody and has a surface temperature of 6000K, its blackbody curve would look like the one in this simulation.

The wavelength of the curve's peak is related to the temperature of the blackbody object by $T = \frac{2.9\times10^6}{\lambda_{max}}$, where λ_{max} is the wavelength of the peak in nanometer.

33. For each of the stars, use the peak wavelength recorded in question 32 to find the surface temperature. Show your work and units. Compare your result to the temperature setting in your simulation. Comment on whether or not your result matched the setting (hint, it should).

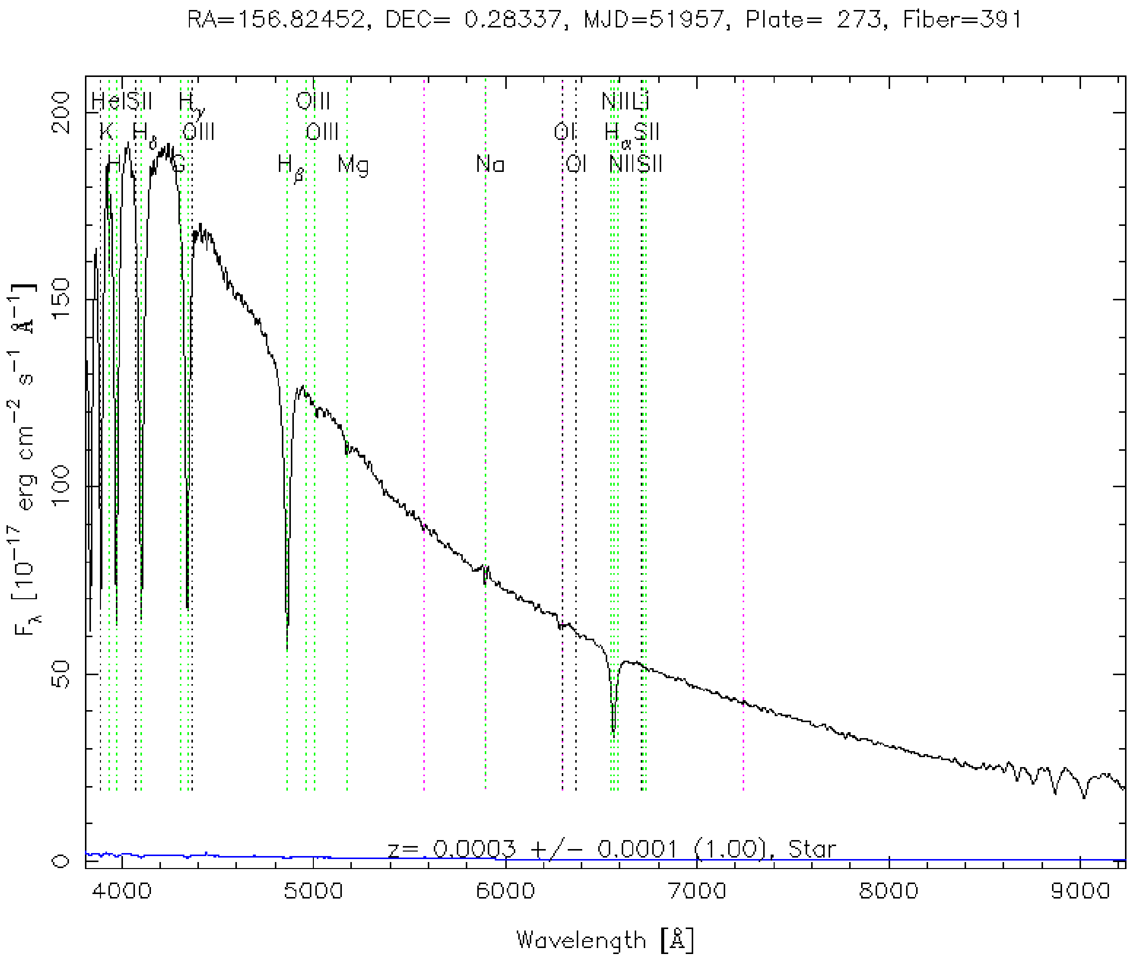
____

____

34. In the following sentence, circle the correct choice of words. "A star with a higher temperature will have the spectrum peak at longer/shorter wavelengths. Light with shorter wavelength has a blue/red color. Therefore, a star with a higher temperature would appear blue/red."

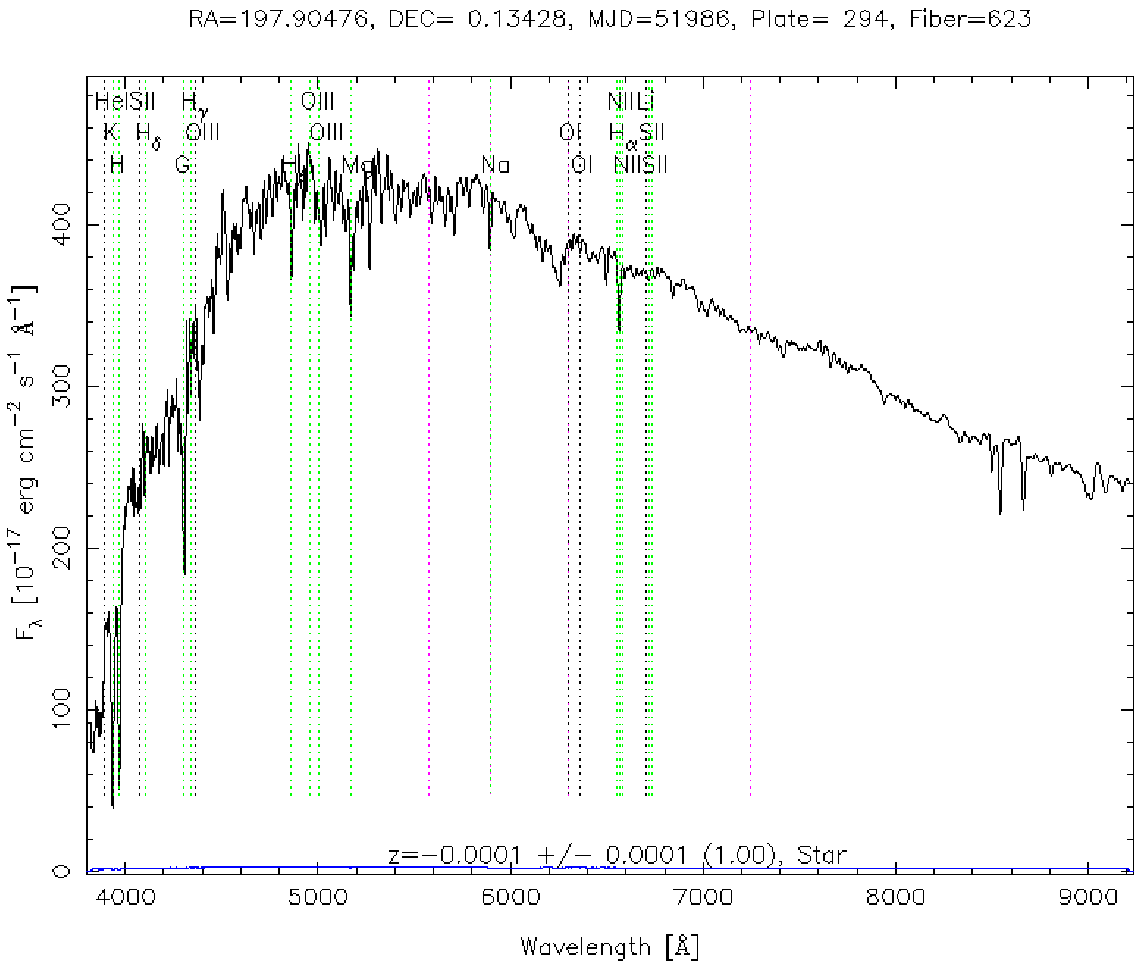
Below are absorption line spectra of two stars. These spectra are more realistic since they show many absorption lines rather than smooth, continuous spectra.

35. For each spectrum, estimate the wavelength of the curve's peak. You have to imagine a smooth continuous line like the simulation, without the absorption lines. Once you have estimated the wavelength, find the surface temperatures. Since the wavelength is recorded in angstrom, the equation to use this time is $T = \frac{2.9\times10^7}{\lambda_{max}}$. Show all work and units.



Peak wavelength ________________ Å

Surface temperature __________________________________



Peak wavelength ___________________ Å

Surface Temperature ____________________________

Takeaway: When we observe stars, we can collect its light and examine the flux of each color. From the absorption lines, we can learn the composition of the surface of the star. From the wavelength of the peak of the curve, we can determine the temperature of a star. We can learn so much from a simple blackbody plot!

Hubble's Constant

Doppler's Effect

When a light source travel towards or away from us, the observed spectra will be shifted

Go to https://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Doppler_Nav.swf::Doppler%20Shift%20Interactive. The red circle depicts a star emitting light. The emitted circles are the emitted light. The spaceship depicts a scientist observing the red star. In the bottom left window, you can see the wave of light that the scientist observes.

1. In the bottom middle, click the button that says "source approaches". As the star approaches, what happens to the wavelength that the scientist observes? Does it become shorter or longer? Click "reset" and "source approaches" to see again.

____

____

____

2. Knowing what you learned from the spectroscopy lab, what color is associated with shorter wavelength? Red/blue circle one.
3. After the star passes the scientist and moves away, what happens to the wavelength that the scientist observes?

____

____

____

4. Knowing what you learned from the spectroscopy lab, what color is associated with longer wavelength? Red/blue circle one

Click "Reset". Pay attention to the wavelength, and remember it. Then click on "Observer Approaches".

5. As the scientist moves towards the star, what happens to the wavelength that the scientist observes? It is longer or shorter compared to when the scientist is at rest?

____

____

____

6. As the scientist moves away from the star, what happens to the wavelength that the scientist observes?

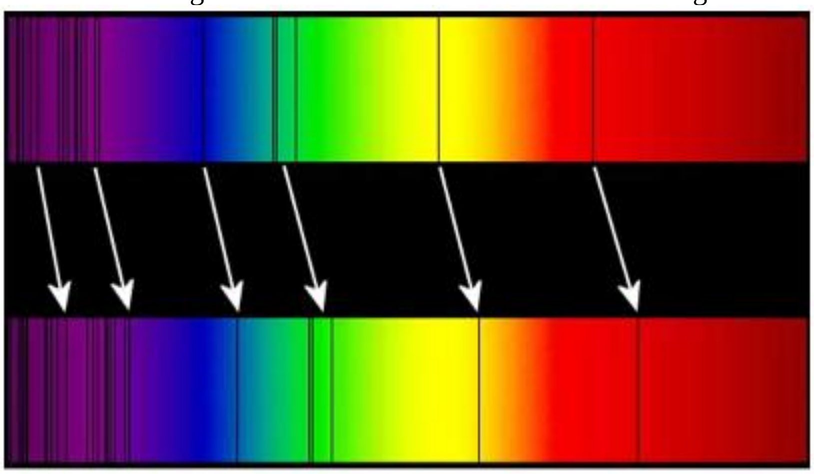
____

____

____

Takeaway: When a star moves towards an observer, the wavelength become shorter and the observer sees the light shifted towards the blue spectrum. When a star moves away from an observer, the wavelength becomes stretched and the observer sees the light shifted towards the red spectrum. This is the same if the observer moves towards or away from the source.

7. In the figure bellow, the spectrum on the top is a stationary. The spectrum on the bottom is from a moving star. In which direction is the star moving?



____

Usually the amount of shift is very small. You will not see a star literally turn red or blue. Rather, you would observe the original spectrum shifted a tiiiiinnnny bit towards the red or the blue end of the spectrum. We will see later in the lab that some objects in the universe show extremely large shifts.

The amount of shift tells us the speed

By observing the shift in the spectrum, the speed in which the star or the observer is moving can be determined by $V = c \times \frac{\Delta\lambda}{\lambda_\circ}$. V is the velocity of the star. c is the speed of light. $\Delta\lambda$ is the change in the wavelength. λ_o is the wavelength that the star is emitting, which is the wavelength of the light at rest.

Example: Hα spectral line has a wavelength of 656.285 nm. The Hα from the star Vega is measured at 656.255 nm. Vega is moving at:

$V = 3 \times 10^8 m/s \times \frac{656.285\times10^{-9}m - 656.255\times10^{-9}m}{656.285\times10^{-9}m} = 13.714 km/s$ Towards us.

8. There is an ambulance that emits sound wave of 1m in wavelength. Suppose we hear the sound wave with a wavelength of 1.3m. Sound travels in air with a speed of 343 m/s (not speed of light!). Calculate the speed of the ambulance. Is the ambulance moving away or towards us?

____

9. Suppose the same ambulance emits soundwave with a wavelength of 1m, and we hear the sound with a soundwave of 1.5m. Calculate the speed of the ambulance.

____

10. Compare your answers to questions 8 and 9. Which is moving faster? Which wavelength had a larger shift?

____

____

____

Takeaway: Stars or galaxies with high speed with respect our line of sight will show a large shift, whether it is towards us or away from us. A star that is moving away from us at high speed will produce a spectrum that is very, very redshifted. A star that is moving towards us at high speed will produce a spectrum that is very, very blueshifted.

Magnitudes and Distance

Distance determines how bright a star looks

A star's energy output is measured by numbers called magnitude. There are two types of magnitudes. Apparent Magnitude measures how much light reaches Earth (how bright it looks). Absolute Magnitude measures how bright stars would appear if the stars were observed from the same distance. The smaller the number, the brighter it is.

11. Vega has an apparent magnitude of 0.03. Deneb has an apparent magnitude of 1.25. Which star appears brighter?

____

12. Based on your answer to question 9, can you determine which star will have a larger Absolute Magnitude? Why or why not? If yes, which will have a larger absolute magnitude?

____

____

____

Takeaway; Stars appear brighter because they actually produce that much light (luminous), or because they are close to Earth. Absolute Magnitude measure the star's brightness from the same distance, so it is a measure of luminosity. There are numerous ways to determine Absolute Magnitude. We will not discuss the method in this lab.

We can determine distance by knowing absolute and apparent magnitudes

Apparent magnitude is determined by observing how much light enters the detector. Absolute magnitude is known for many cases. Then the distance to the object is determined by $D = 10 \times 10^{\left(\frac{m-M}{5}\right)}$. m is the apparent magnitude. M is the absolute magnitude. Distance is measured in parsec (pc). 1 pc is about 3.26 LY.

For example, Vega has an apparent magnitude of 0.03 and absolute magnitude of 0.58. Then Vega is

$D = 10 \times 10^{\left(\frac{0.03-0.58}{5}\right)} = 10 \times 10^{-0.11} = 7.76pc = 25.31L$ away from Earth.

13. Deneb has an apparent magnitude of 1.25 and absolute magnitude of -8.73. Calculate the distance to Deneb in pc.

____

Hubble's Law

Hubble discovered that distant galaxies move at high speed

In the 1920s, Edwin Hubble observed numerous galaxies and determined their speed and distances. In this part of the lab, we will retrace Hubble's steps to understand his remarkable discovery.

14. Below is a table of several galaxies along with their apparent magnitude. Assume that all galaxies have absolute magnitude of -22. Complete the table.

Galaxy	Apparent magnitude	m-M	Galaxy	Apparent Magnitude	m-M
A	14.95		J	16.59	
B	13.44		K	14.81	
C	16.71		L	16.16	
D	15.32		M	16.94	
E	16.94		N	15.21	
F	16.16		O	16.00	
G	14.66		P	16.59	
H	14.83		Q	14.95	
I	16.71				

15. Use the equation from Question 13 to determine the distance of each galaxy in parsec, then convert it to MLY.

For example, a galaxy is 13,255,637 pc away. Then this galaxy is

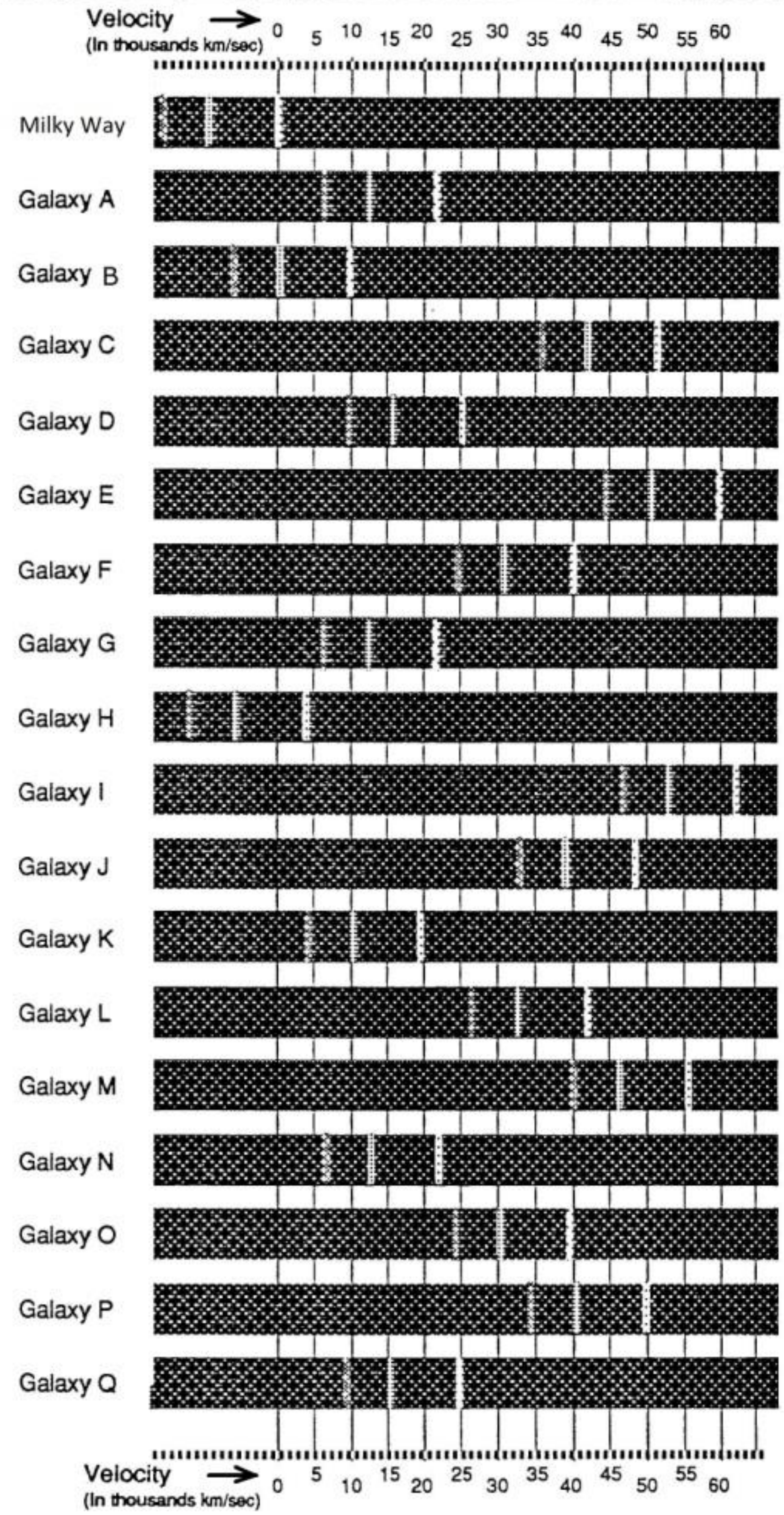
$13{,}255{,}637pc \times 3.26\, {}^{LY}\!/_{pc} \times 10^{-6}\, {}^{MLY}\!/_{LY} = 43.213MLY$ away.

Show an example work for one of the galaxies. Keep 3 decimal points. Complete the table in page 8.

Now we will determine the speed of each galaxies. Below is a picture showing the spectra of all the galaxies. The first galaxy is the Milky Way galaxy. This will be the galaxy that is "at rest". Notice that you see 3 emission lines in the spectrum. All the other galaxies also show the same emission line spectra, but they are heavily shifted.

16. Are all the galaxies redshifted or blue shifted? ___________________________
17. From the plot estimate the recessional speed of each galaxies. The shows that the right-most line of the Milky Way Galaxy spectrum is set to $0X10^3$ km/s. All you have to do is to determine how much the right-most line of all the galaxy spectra are shifted, and record the velocity.

Spectra of Fast Moving Galaxies



Galaxy	Distance (MLY)	Velocity (10^3 km/s)	Galaxy	Distance (MLY)	Velocity (10^3 km/s)
A			J		
B			K		
C			L		
D			M		
E			N		
F			O		
G			P		
H			Q		
I					

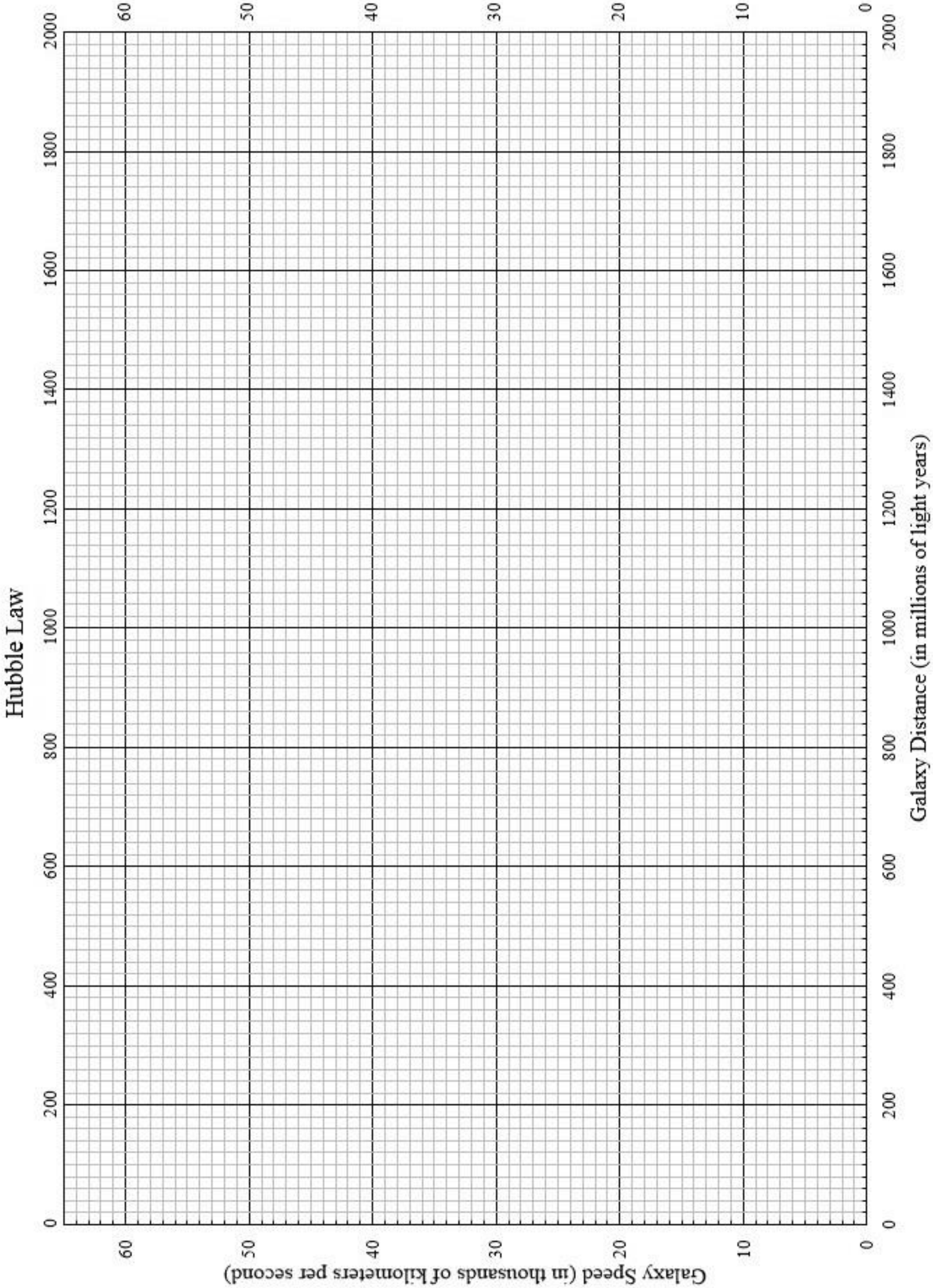
18. Use this table to plot speed vs. distance in the graph below.
19. What can you say about the relationship between the galaxies' distances from us and their recessional speeds? If a galaxy is far away from us, does it move at a higher or lower speed?

____

____

____

Takeaway: Hubble discovered that distant galaxies move away at a high speed from the Milky Way galaxy. However, the galaxies are not selectively moving away from the Milky Way. The universe is expanding and dragging all the galaxies with it. Suppose our classroom stretched and dragged all chairs apart. Students near edge of the classroom will see the other end of the classroom move quicker than their peers. Hubble discovered that the universe is expanding!


Hubble Law
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Galaxy Distance (in millions of light years)
0
10
20
30
40
50
60
Galaxy Speed (in thousands of kilometers per second)

Show all your work! Note: For your guidance in these calculations, approximate values for the answers are given in parenthesis beside each answer. These values are given as ballpark figures, and you should record your calculated answer even if it is not exactly the same.

20. After graphing all of the galaxies, make a best-fit linear line (straight line) that fits your data and that goes through the point (0,0). The line should not connect all the points. Rather, the line should end with about half of the points above the line and the other half below the line.
21. Use this line to calculate the slope of the line, which is the Hubble constant. First, pick a single point **on** your best-fit line, **near the upper right of your graph**. As high as possible. *You should pick a point ON your best fit line (not one of your data point), and it should be at the upper right of your line. If your point does not meet the criteria, you will not receive credit for the rest of the lab*

Velocity of the point you picked: ______________

Distance of the point you picked: ______________

22. The slope of the line (which is also the Hubble constant) is the velocity of the point you picked, divided by the distance of the point you picked. Show work and units.

Using the Graph: Average Value of H_0 = ___________10^3 km/sec/MLY ($2.85X10^{-2}$)

Takeaway: This is the famous Hubble Constant! Your best fit line is simply a straight line that goes through (0,0), which follows the form y=mx. With our plot, this is $V=H_oD$, called the Hubble's Law.

The Age of the Universe

The Hubble Law can be used to determine the age of the universe.

First, we will go through a series of example calculations to see how this is determined.

23. Using ***your*** average value of $\mathbf{H_0}$ determined from your graph, and Hubble's Law, calculate the recessional velocity of a galaxy that is 2,000 MLY away. Show work.

V = _______10^3 km/sec *(57)*

Think about a trip in your car. If you tell a friend that you are 120 miles away from your starting point and that you traveled 60 miles per hour, your friend would know you had been traveling two hours. That is, your trip started two hours ago. You know this from the relationship:

Distance = Rate (or velocity) X Time, which we can write as D = VxT.

We can rewrite this as T = D/V. Thus, 120mi/60 (mi/hr) = 2 hours.

24. Now let's determine when the universe "started its trip". The distance is 2,000 MLY, but first convert MLY into km because the velocity is in km/sec. One MLY is $9.461x10^{18}$ km)

D = _____________km *(2×10^{22})*

25. Use the equation above to determine how many seconds ago the universe started. Don't forget the 10^3.

T = ____________secs *(4×10^{17})*

26. There are about 3.15×10^7 seconds in one year. Convert your answer into years:

T = _______ years (1.2×10^{10})

27. Therefore, the age of the universe is approximately _____ billion years old. (12 billion years)
28. When you calculated the age of the universe, you found out how long it took a galaxy to get where it is today, based on knowing its distance and its velocity. If the Hubble constant were a bigger number, how would the age of the Universe change? Explain your answer.

---

29. If the Hubble constant were a smaller number, how would the age of the Universe change? Explain your answer.

---

30. Student A drives from SoCal to Las Vegas at a constant speed of 75 miles per hour. Student B also drives from SoCal to Las Vegas, but B starts by going 50 miles per hour, and gradually speed up the entire time so that, by the time B gets to Las Vegas, B is going 75 miles per hour. Who will get there first? Why?

---

31. We now know that the Universe is actually accelerating, meaning the Hubble constant isn't really a constant. Instead, it is increasing as time goes on, and the Hubble "Constant" of 72 km/sec/Mpc that we measure really just tells you how fast the universe is expanding right now. Does that mean the Universe is actually older or younger than what you calculated above? Explain your answer.

Takeaway: Using Hubble's law, we can simply estimate the age of the universe. This is assuming that the universe has been expanding at a constant rate. We now know that the expansion of the universe is accelerating, so it is not as simple to determine the accurate age. Scientist need to study more distant galaxies to get an accurate number for the Hubble's constant, and the age of the universe.

Galaxies

Edwin Hubble

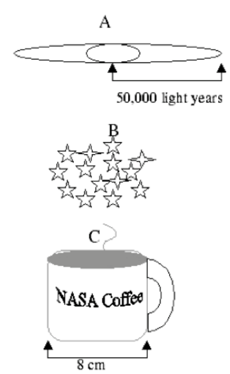
In the 19th century, astronomers thought that the Milky Way was the only galaxy in the universe. The introduction of telescopes to the study of astronomy opened up the universe, but it took some time for astronomers to realize the vastness of the universe. Telescopes were used to make dim objects in the sky look brighter and small objects look larger. There are two types of telescopes: a refractor, which uses a lens to collect light, and a reflector, which uses a mirror to collect light. Telescopes revealed that our night sky was not only populated with stars, but with other objects which appeared like faint, patchy clouds. These objects were nebulae that seemed to be within our Galaxy, the Milky Way, and thus believed to be relatively close. But as telescopes became more powerful, it was possible to see different structures in the nebulae.

Astronomers debated the nature of these nebulae. The question became whether these objects were within the Milky Way Galaxy, or whether they were stellar communities distinct from our Galaxy. It wasn't until the 1920's that the American astronomer, Edwin Hubble, ended the debate by discovering that some of the nebulae were composed of stars. Hubble also determined the distances to these particular nebulae, and found that they were far outside our Galaxy. Thus, these were found to be individual galaxies. Scientists now estimate that there are about 200 billion galaxies of various types in the universe.

How Big is the Universe?

The Milky Way has a radius of approximately 50,000 light years. The visible universe has a size of approximately 15 billion light years.
What is the total diameter size of the Milky Way Galaxy? ___________________________

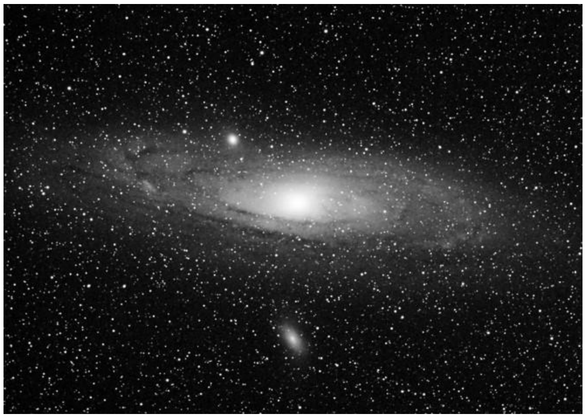
If the Milky Way is represented by an 8 cm wide coffee cup, how big would the rest of the universe be in kilometers? Show work and units.



$$Scaled\ Universe\ size = \frac{Scaled\ Milky\ Way\ size}{Actual\ Milky\ Way\ size} \times Actual\ Universe\ size$$

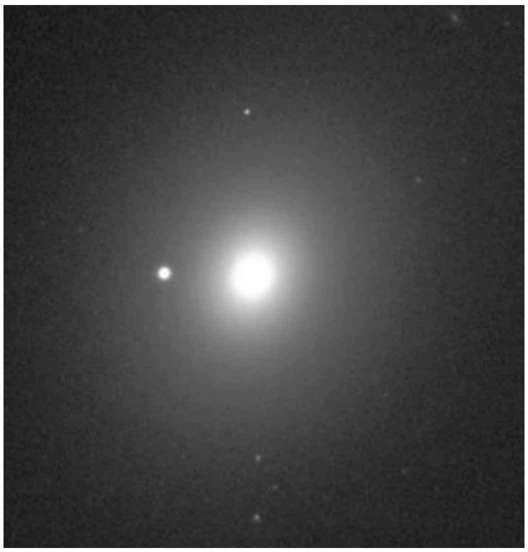
1km = 10^5cm

___________________________________ km in diameter.



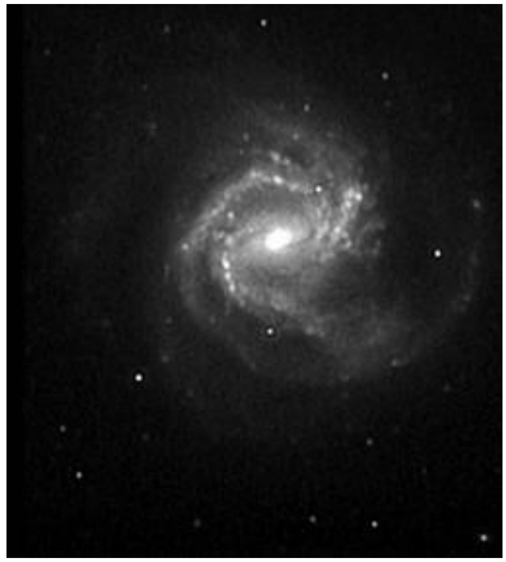
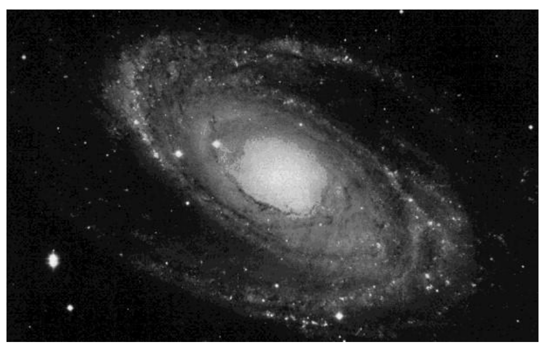
1) M31

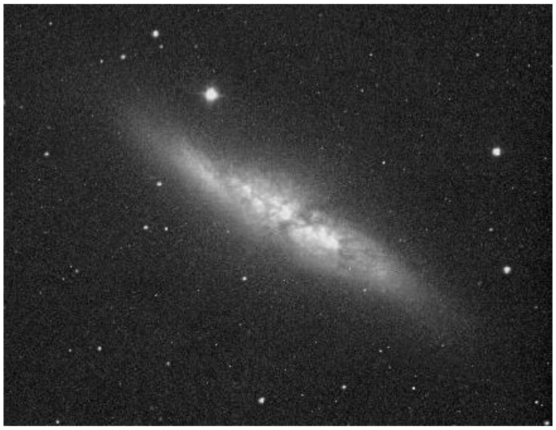
2) M32



3) M49

4) M51

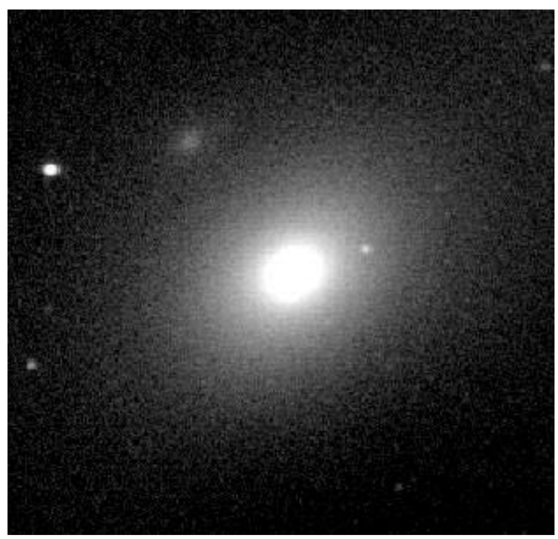
 5) M59	 6) M61
 7) M64	 8) M81



9) M82

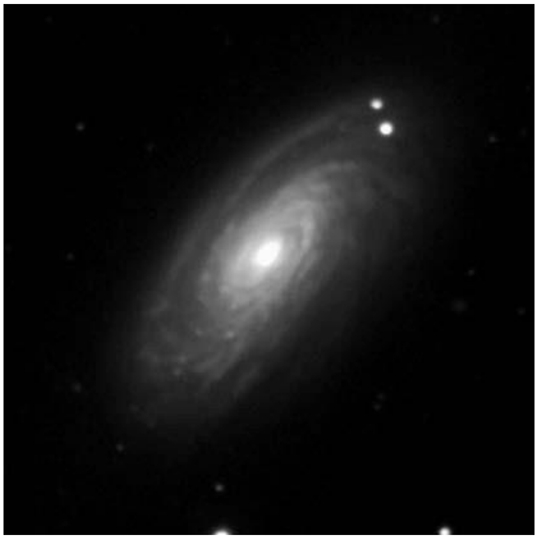
10) M83

11) M84



12) M86

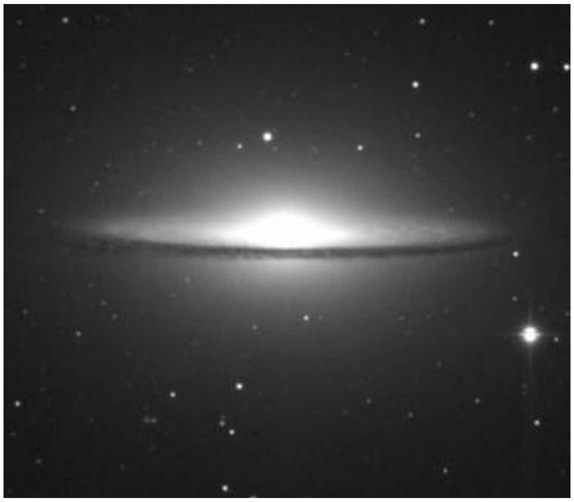
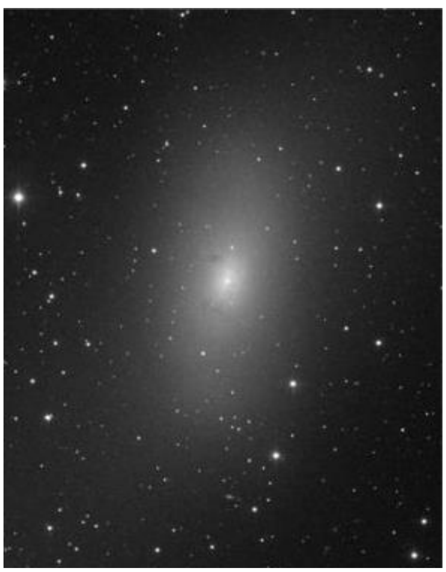
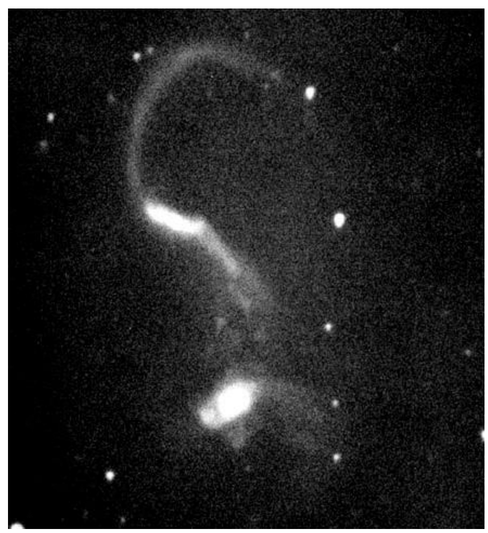
13) M87

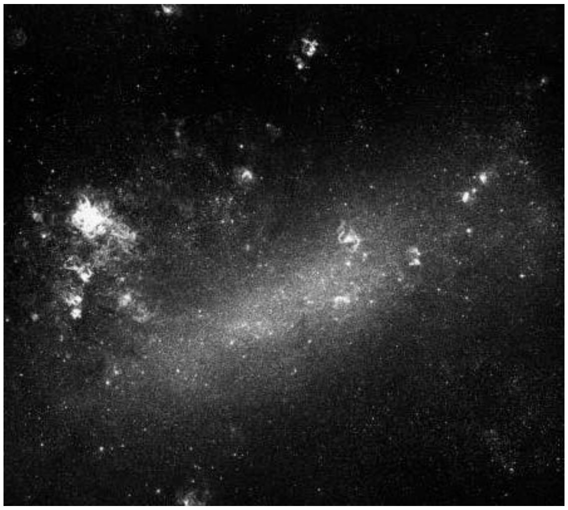


14) M88

15) M89

16) M101

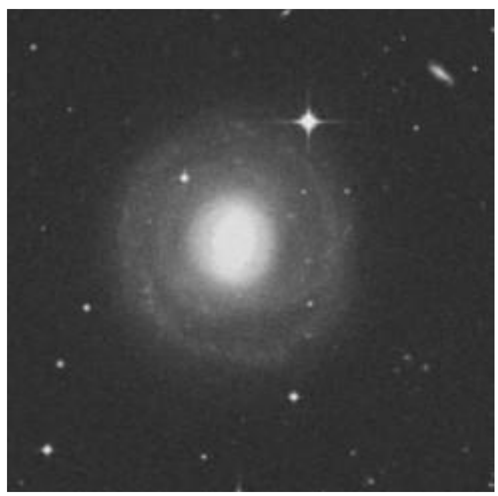
 17) M104	 18) M109
 19) M110	 20) Arp 252



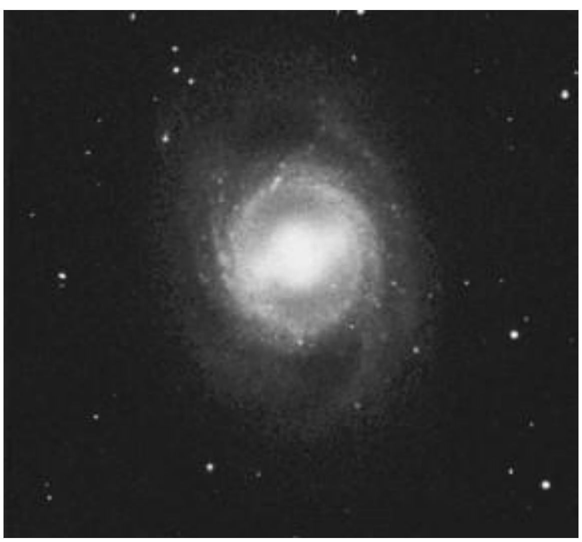
21) LMC

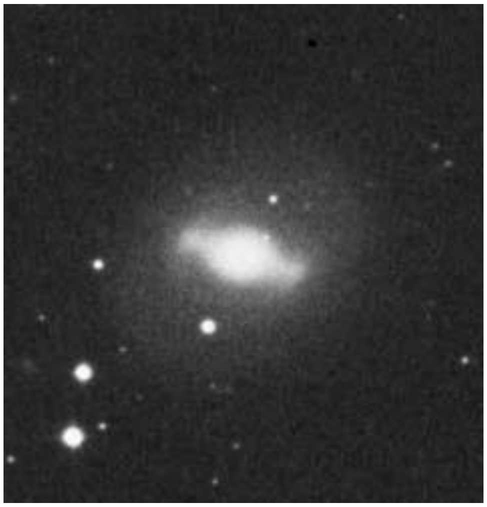
22) Leo I

23) NGC 253

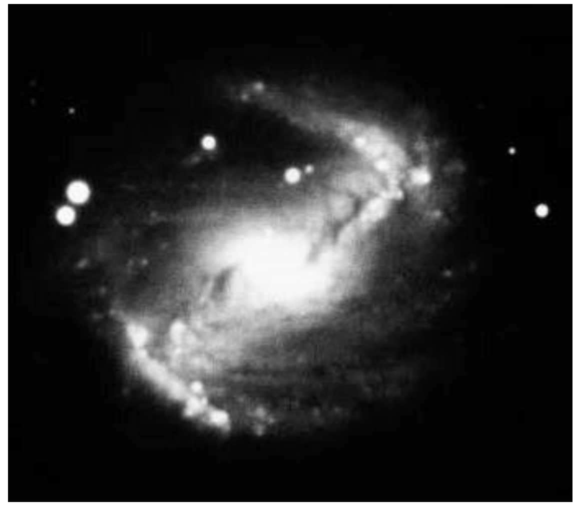


24) NGC 1302

 25) NGC 1365	 26) NGC 2146
 27) NGC 3351	 28) NGC 4565



29) NGC 4596



30) NGC 5383

31) NGC 6946

32) NGC 7743

Hubble's tuning fork diagram

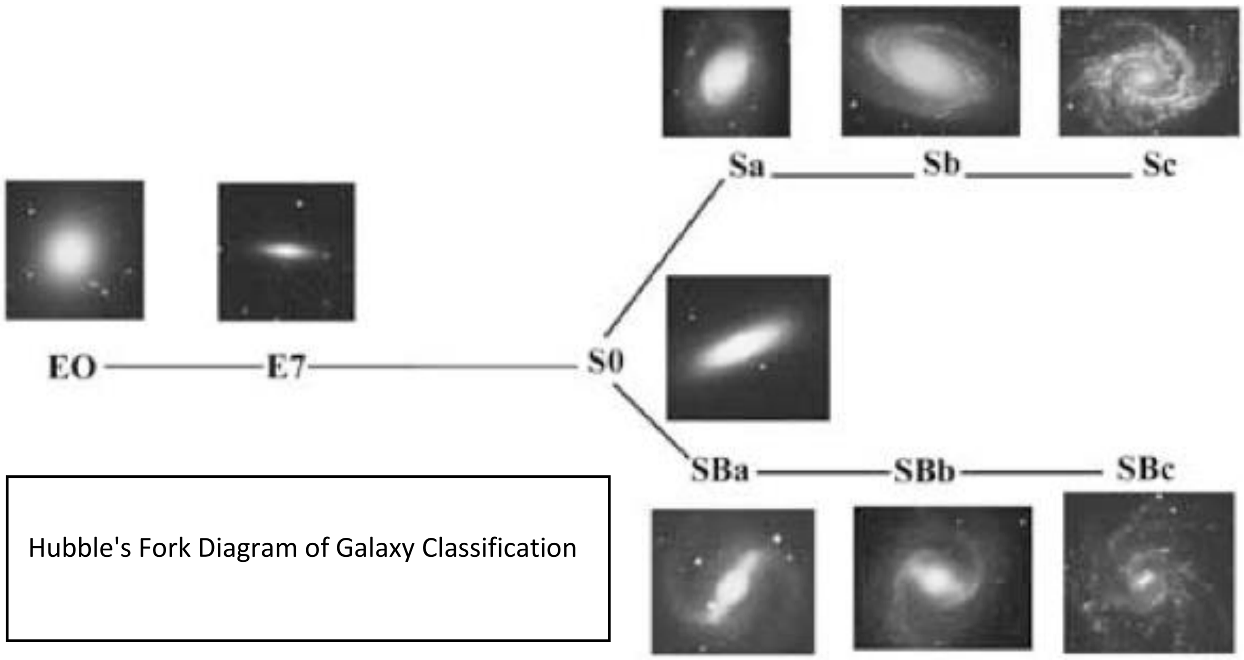
Astronomers use the classification scheme that Edwin Hubble developed in the 1920s. He categorized (or "classified") their shapes as **spiral, barred spiral, elliptical, irregular, and peculiar**. This system was known as the Hubble morphological sequence of galaxy types.

Hubble noted that some galaxies, like the M31- Andromeda Galaxy, appeared as disks and had arms of stars and dust which appeared in a spiral pattern. Like M31, these galaxies appeared nearly uniform in brightness. In addition, Hubble observed that in some of these types of galaxies the arms were more tightly wound around the galaxy. He called these spiral galaxies. Our Galaxy, the Milky Way, is an example of a spiral galaxy.

Hubble also noted that some spirals had a bright bar of gas through the center, and called these barred spirals. Hubble also discovered galaxies that were slightly elliptical in shape, while others were nearly circular, such as M32. He called these elliptical galaxies. The fourth type of galaxy observed was neither spiral nor elliptical, but was irregular in shape. These galaxies were called irregular. An example of this is the Magellanic Clouds. Finally, there were some galaxies that fit none of these descriptions. These were called peculiar galaxies, one example of which is Centaurus A.

This classification sequence has become so widely used that the basic types, spiral, barred spiral, elliptical, irregular, and peculiar, are still used by astronomers today to classify galaxies according to their visible appearance. Spirals are denoted by "S", and barred spirals by "SB". Letters "a", "b", "c" denote how tightly the spiral arms are wound, with "a" being most tightly wound. The Andromeda Galaxy is an Sb. Elliptical galaxies are denoted by "E", with a number from 0-7 indicating how circular it appears (0 being most circular, 7 being more elongated). An example of this would be M87, which is an E0 galaxy. Irregulars, such as the Small Magellanic Cloud, are denoted by "Irr". Peculiar galaxies, such as Centaurus A, are denoted by "P".

To show how the various classes relate to each other, Hubble organized them into a diagram. A simplified version of Hubble's Fork Diagram is shown below. Note that this diagram does not represent how galaxies form.



Hubble's Fork Diagram of Galaxy Classification

1. Study the “types of galaxies” picture in the next page. List the five types of galaxies and write a brief description of each in your own words.

Spiral:

____

Bar Spiral

____

Elliptical

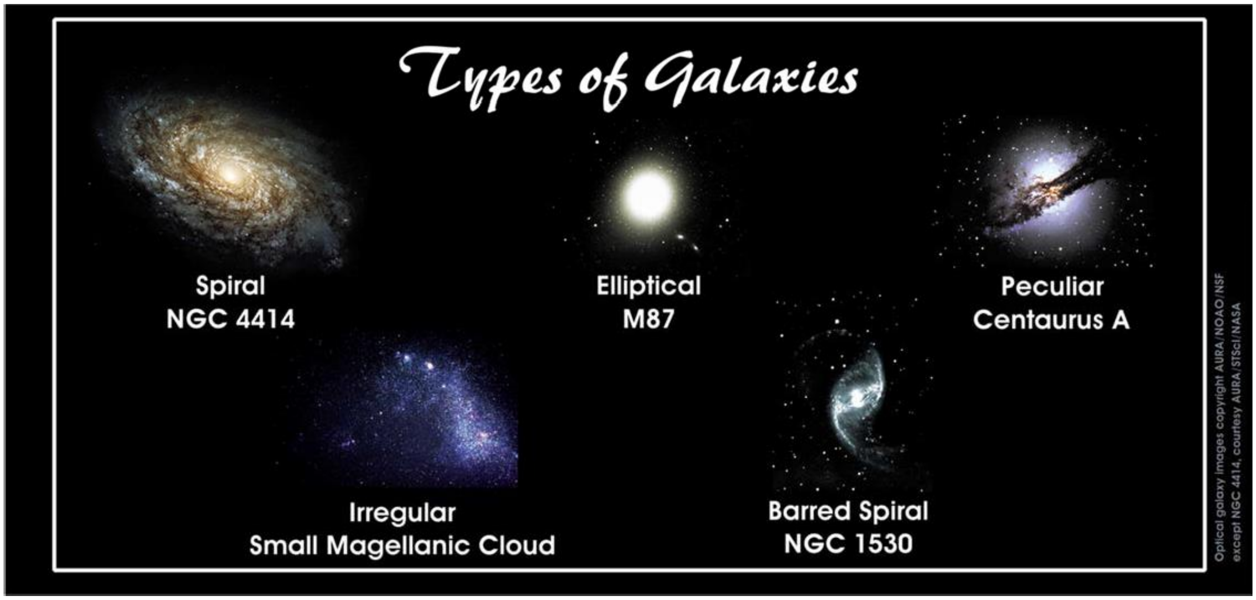
____

Irregular

____

Peculiar

____



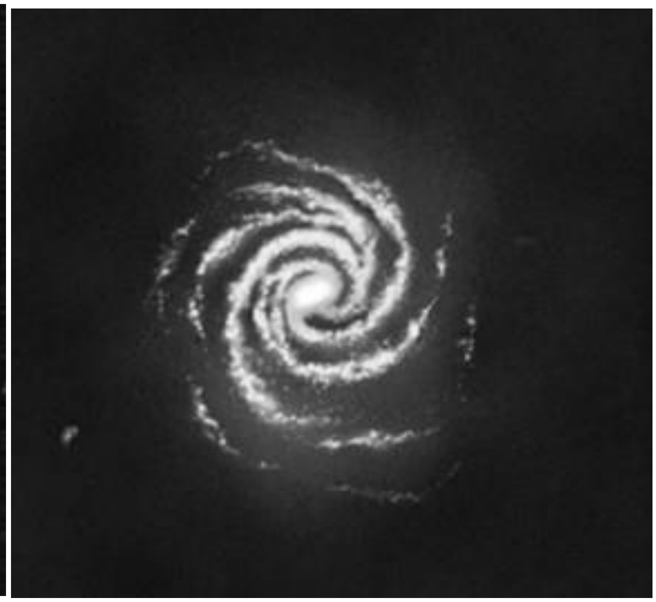
2. In the previous pages are 32 pictures of galaxies. Take a good look at them. Separate them if you have to. In the table below write the Hubble class (E4, SBa, etc) each galaxy belongs to. This is NOT an exact science, so answers that are close will get credit.

Galaxy	**Class**	**Galaxy**	**Class**
1) M31		17) M104	
2) M32		18) M109	
3) M49		19) M110	
4) M51		20) Arp 252	
5) M59		21) LMC	
6) M61		22) Leo I	
7) M64		23) NGC 253	
8) M81		24) NGC 1302	
9) M82		25) NGC 1365	
10) M83		26) NGC 2146	
11) M84		27) NGC 3351	

12) M86		28) NGC 4565	
13) M87		29) NGC 4596	
14) M88		30) NGC 5383	
15) M89		31) NGC 6946	
16) M101		32) NGC 7743	
NGC 1201		Milky Way	

3. Here are two extra galaxies. According to your method, what category would each be?

NGC 1201



The Milky Way – Artist's conception

_______________________________ _______________________________

Watch the video on Canvas under the **Galaxies** and answer the following questions:

1. People realized that nebulae were galaxies, and called them ______________________________
2. Before he was an astronomer, Edwin Hubble was a ___________________
3. The more distance an object is, the ______________________ in time we are observing.
4. When we observe the center of the Milky Way, we are observing it as it was, ________________ years ago.
5. The further away the galaxy is, the greater/smaller the recessional speed.
6. Large galaxies are usually elliptical/spiral/irregular.
7. To study the evolution of galaxies, scientists had to study the _____________ type.
8. Peculiar galaxies are like irregular but they have a ______________ to it.
9. Now scientists think that after galaxies ______________ they form _____________ type galaxies
10. Galaxies merge because they form in __________________.
11. Galaxies look dense but when they collide, stars will/will not collide.
12. If a galaxy passes right through another galaxy, it can take a shape of a ________________
13. In the early universe, there were more elliptical/spiral galaxies than elliptical/spiral.

Galaxy Zoo Lab

Galaxy Zoo is a program that allows “citizen scientists” to assist with the very time-consuming task of classifying galaxies observed by telescopes from around (and in orbit above) the world. In this activity, you will use your newly found galaxy classification skills to help astronomers learn about the universe around us.

1. Go to www.galaxyzoo.org
2. Click on the yellow/green button that says “Classic”.
3. On each page, you will be shown a picture of a galaxy. Answer the questions that are posed to you about the galaxy you see. If you are unsure how to answer any of the questions, you can click on the button that says “Examples” to see example images that illustrate what you should be looking for.
4. As you answer the questions online, write tally marks on the table to keep track of how many galaxies you see of each type. For each galaxy, also determine whether you think the galaxy you observed is an elliptical, barred spiral, regular spiral, or irregular galaxy, based on Edwin Hubble’s classification scheme.
5. Once you have classified 10 galaxies, write your totals for each Hubble type on Canvas, then share your data with 4 other students, so you will have Hubble galaxy types for 50 galaxies overall. Finally, answer the questions.

6. Which of the Hubble Types of galaxies was the easiest to identify from the images? Which was the most difficult? What made some more difficult than others? Explain.

___

___

___

___

7. How confident are you that you categorized each of the galaxies correctly? Is it possible that some of the galaxies were actual a different type than what you selected? Explain how likely you think it is that you miscategorized some of the galaxies.

___

___

Galaxy Zoo Classification:

Smooth		
Round	In Between	Cigar Shaped

Features or Disk			
Could be a Disk Viewed Edge On			Could Not Be
Rounded Bulge	Boxy Bulge	No Bulge	
Yes Bar		No Bar	
No Spiral Arms	Tight Spiral Arms	Medium Spiral Arms	Loose Spiral Arms

Star or Artifact

Anything Strange?

No	Ring	Arc	Disturbed	Irregular	Merger	Dust Lane	Overlapping	Other

Hubble Classification:

Elliptical	Barred Spiral	Regular Spiral	Irregular

Number of Each Galaxy Type

Galaxy Type	Your Data	Classmate 1	Classmate 2	Classmate 3	Classmate 4	Total
Elliptical						
Barred Spiral						
Regular Spiral						
Irregular						

1. Calculate what percentage of each galaxy type you and your classmates observed, using this equation, and fill in the following chart.

$$\%\ of\ galaxy\ type\ X = \frac{number\ of\ galaxies\ of\ type\ X}{total\ number\ of\ galaxies} \times 100$$

Show one work example.

Galaxy Type	Percentage From Your Data	Percentage from You and Your Classmates
Elliptical		
Barred Spiral		
Regular Spiral		
Irregular		

2. Which type of galaxy was the most common in your data? What percentage of the galaxies were this type?

3. Which type of galaxy was the most common in the data from you and your classmates? What percentage of the galaxies were this type?

4. Compare the percentages of the galaxy types you found to those found by you and your classmates together. What similarities and differences do you see? Explain.

5. Which percentage do you think is more likely to match the galaxy percentages for the entire universe, the percentages from your data alone, or the percentages from you and your classmates combined? Explain.

6. What would you do to improve your data? How could you redesign your experiment to make your overall percentages better match the percentages that actually exist in the universe?