The Great Big Astro Lab Manual: Worksheet Master Document

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For usage instructions, please reference The Great Big Astro Lab Manual, Section 0.4: Using `.tex` files.

0 General

0.1 Syllabus

0.2 Stellarium Guide

0.2.1 Installation

You can download Stellarium for your own computer (Mac, Windows, Linux) at `http://www.stellarium.org`. The software is free, and there are links to extensive documentation on the website.

0.2.2 Quick Usage Guide

After installing it, use the following walk-through to familiarise yourself with the basics of how the program works.

N.B.: If pressing the function keys (F1 – F12) isn't working, press down the Fn key (keyboard lower left corner) and press the function key.

1. Open Stellarium.
2. The default location is Paris (seen in the lower left corner). For observations made from Amherst, we need to change the location.
   i. Move the cursor to the lower-left side of the window and click on "Location Window", or press F6.
   ii. In the "Location" window, in the entry field next to the magnifying glass (for searching), type "Amherst". Then, click on "Amherst Center, United States". (**DO NOT** type "Amherst" into Name/City. It will just rename Paris to Amherst, but won't change the location. Also **DO NOT** select "Amherst, United States".)
   iii. Close the window by clicking on the cross (×) in the upper right corner.
3. Change the Date/Time to a value, e.g. 2015/09/01, 14:00:00.
   i. Move the cursor to the lower-left side of the window and click on "Date/Time Window", or press F5.
   ii. Change the date and time either by entering the values directly or using the arrow keys to increase or decrease the values.
   iii. Close the window by clicking on the cross (×) in the upper right corner.
4. Click and hold the cursor on a spot in the window, and drag it around to look in various directions.
5. Zoom in by scrolling **UP** and zoom out by scrolling **DOWN** (on touchpad, mousepad, mouse, etc.)
6. Zoom out till you see the full sky in your screen. You should see only the Sun.
   i. To turn on and off the atmosphere visualisation, move the cursor to the bottom of the window on the left side and click on the cloud icon, or press A.

ii. To turn on and off the ground visualisation, move the cursor to the bottom of the window on the left side and click on the trees icon, or press G.

iii. To turn on and off the constellation lines, move the cursor to the bottom of the window on the left side and click on the "N"-shaped icon, or press C.

iv. To turn on and off the constellation names, move the cursor to the bottom of the window on the left side and click on the mirrored "N"-shaped icon, or press V.

v. To turn on and off the constellation art, move the cursor to the bottom of the window on the left side and click on the person-shaped icon, or press R.

vi. To turn on and off the stars, press S.

7. Click on Saturn. Notice that some information about Saturn pops up at upper left corner of the window.

   i. Press the space bar to center the view on the selected object, Saturn.

   ii. Zoom in until the field of view (FOV at the bottom of screen) is $0.1°$. What objects other than Saturn can you see?

   iii. To start and stop the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "play" icon, or press K.

   iv. To increase the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "fast forward" icon, or press L.

   v. To decrease the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "rewind" icon, or press J.

   vi. To return to the present time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "hourglass" (2 triangles vertically stacked, points facing each other) icon, or press 8.

8. Search for an object, e.g. the Sun.

   i. Move the cursor to the lower-left side of the window and click on "Search Window", or press F3.

   ii. Enter the name of the object you are searching for.

   iii. Close the window by clicking on the cross ($\times$) in the upper right corner.

9. Play around and familiarise yourself with the software. For help, press F1.

1 Lab 1: Astronomical Angles and Stellarium

1.1 Worksheet

1.1.1 Background Survey on Moodle

Log in to Moodle (on smartphone, laptop, or one of the computers at the table). Go to the section for Astronomy Lab 1 and complete the Astronomy Background Survey. Don't worry if you don't know the answers, just answer every question as best you can and you will receive full credit.

1.1.2 Stellarium

Stellarium is a planetarium software that helps us visualise the sky over time. We'll use it to begin our exploration of astronomy.

1. Go to `http://stellarium.org/` and download and install the correct version for your operating system. If you can't find it, use Stellarium Web.
2. Open the Location Window from the left-hand menu panel or by pressing F6. In the search bar under the top right, menu type "Amherst" and select "Amherst Center, United States".
   - Make sure it's "Amherst Center", not "Amherst" (that's in NY somewhere).
   - **Do not type** into the "Name/City" box. That renames the location.
3. Close the Location Window and open the Date/Time Window from the left-hand menu panel or by pressing F5. Set the time to 7:00pm tonight. Close the window.
4. Look at what the sky will look like tonight. Drag the view and scroll up or down to zoom in or out respectively.

1.1.3 Positions of Astronomical Objects

In astronomy, we use angles to measure positions and separations of objects in the sky. From your point of view, an object's position is given by **azimuth** and **altitude**. Answer the following questions.

1. How many degrees are in a circle?
2. How many degrees are in a right angle?
3. What are longitude and latitude?
4. What is the azimuth/altitude system?

Astronomers use the **sexagesimal** system for recording angles. Each degree is divided into 60 **arc minutes** ($'$), and each arc minute is divided into 60 **arc seconds** ($''$). An azimuth of $240°38'12''$ is read as 240 degrees, 38 arc minutes, and 12 arc seconds.

Set the time to 2022/1/31 at 6:00pm. Locate the object and click on it, then answer the following. At this time, what is the azimuth and altitude of:

Object	Azimuth	Altitude
Betelguese		
Jupiter		
Sirius		

Now advance the time by a few minutes. Do the azimuths and altitudes increase or decrease?

1.1.4 Lab Quiz on Moodle

Go to the Lab 1 section on the Moodle page and complete the End-of-Lab Quiz.

If you logged into your Moodle account from a classroom computer, be sure to log back out!

1.2 Lab 2: Angular Sizes on the Sky

1.2.1 Worksheet

2 Lab 3: Angular Size vs. Distance

2.1 Worksheet

In groups at each table, you will investigate how the angular diameter of a spherical body (a ball) depends on its distance from you.

2.1.1 Data and Graph

1. At your table, discuss and agree on a plan for how to make measurements of the sphere to explore the relationship between its angular size and distance. Consider:

    a. What distances will you make measurements from?

    b. How will you measure the distances?

    c. Will you repeat the measurement with different people? (This is called replication.)

    d. What will you do if points disagree?

2. Make sure each person makes **at least one** measurement of the ball's angular size and distance. Record your measurement below.

    (a) Angular diameter of ball (to nearest half-degree): ____________

    (b) Distance from ball: ____________

    Record all your measurements on the table worksheet. Mark the the position of your measurements at your table to **graph all the points in the table worksheet.**

3. Select someone at your table to **graph all the points in the table worksheet.**

2.1.2 Interpreting the Graph

Look over the points plotted by your group and discuss the following:

1. Do the points exhibit a pattern? How would you describe that pattern in words?

2. How might you describe the relationship mathematically?

3. Do all the points agree with each other? What factors might explain the differences we see?

2.1.3 Angular Size of Astronomical Objects

1. Let's consider the Sun.

    a. Does the Sun's angular size changes during the year?

    b. What month is it the smallest? ____________

2. Now let's look at the Moon.

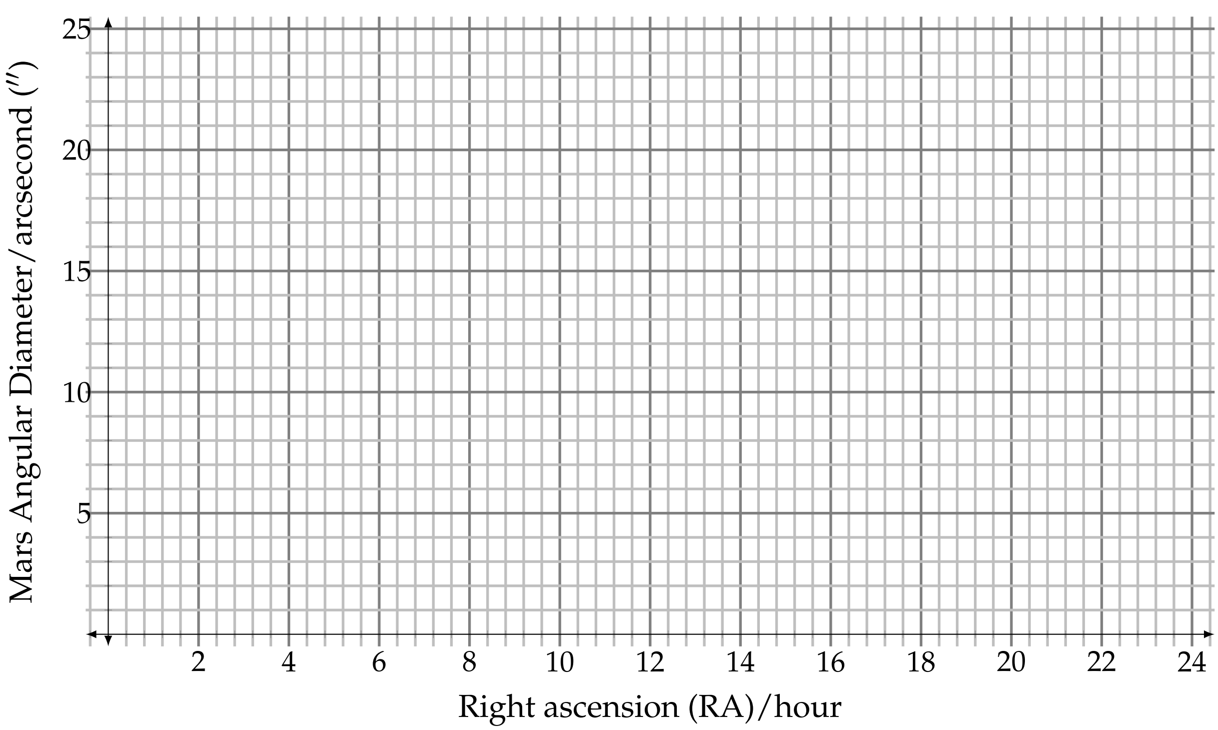
    a. Is the Moon larger when it's full?

    b. What is a supermoon?

    c. Is the Moon larger when it's near the horizon?

The planet Mars shows the greatest variation in size of all the planets, which we will explore here.

1. In groups of 2-3, start up Stellarium. Find where Mars is today. You can turn off the atmosphere (hit A) and ground (hit G) to help.
2. Once you have found Mars, you can click on it and center the view (by pressing the space key). Take note of Mars's angular diameter (given as "Apparent diameter" in the left-hand side info panel.
3. Zoom in until Stellarium renders some surface features.
4. You are going to look at how Mars's **angular diameter** and **right ascension ("RA")** values each change over time. To do this, open the Date/Time window and vary the date from October 2021 to October 2023, one month at a time. At each date, take note of Mars's **angular diameter** and **right ascension ("RA")**. These are the values you will plot (**NOT** the date!).
5. Plot Mars's angular diameter vs. right ascension in the grid below and answer the following questions.



a. How big is Mars in October 2021? __________ arcseconds

b. Where is it in its orbit in October 2021?

c. In what month is Mars largest? __________

d. How big is it that month? __________ arcseconds

e. What explains the pattern of sizes you find in your graph?

2.1.4 Lab Quiz on Moodle

Go to the Lab 3 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

3 Lab 4: Phases of the Moon

3.1 Worksheet

3.1.1 Actual Scale of the Earth and the Moon (Class demo)

1. Suppose the Moon is the size of a golf ball. On this scale, how big is the Earth? **Lower** your hand when you think the demo balloon is at the right size.
2. On this scale, how far would the golf ball Moon be from Earth? **Lower** your hand when you think the demo balloon is at the right distance.

   Relative to the size of the golf ball, this distance is the same as the as the distance from the Earth to the Moon, relative to the size of the real Moon. Hence, **the angular sizes are the same.** If you take a zoomed-in picture of the golf-ball at this distance and compare it to your zoomed-in calibration grid, you will find the golf ball has the same angular size as the real Moon.
3. As part of the extra credit project, take a picture of the golf-ball Moon from the to-scale distance.

3.1.2 Modelling the Moon's Phases

You will each get a golf ball with a hole in it so you can put it on a pen or pencil and hold it up. Each table will have a light source that will represent the Sun.

1. To first understand Earth's rotation in relation to the Sun, begin by picturing your head as the Earth. Imagine the top of your head is the North Pole, with Boston at your left eye, and San Francisco your right eye. Take the light bulb on the table to be the Sun.
   a. Which way does your head face when it is noon in Boston?
   b. Which way does your head face when it is noon in San Francisco?
   c. Which way does your head turn to go from noontime in Boston to noontime in San Francisco?
2. Let's examine the Moon's phases as it orbits the Earth. Make sure that you can see the portion of the Moon lit by the "Sun" in your table.
   a. Look for the **crescent** phase, and estimate the angle between the Sun and the Moon (with the Earth at the vertex) when the Moon is a crescent.
   b. Can you ever see a crescent Moon at midnight?
   c. Where is the Moon when it is **new**?
   d. Where is the Moon when it is **full**?
   e. Where is the Moon when it is **gibbous**?
3. Suppose the Moon is at **first quarter**.

a. When should it cross your **meridian**?
b. When does it rise, and when does it set?

3.1.3 Observing the Moon's Phases

1. In groups of 2-3, start up Stellarium.
2. Set up Stellarium for Amherst Center (F6) on 23 February 2022 (F5). Look toward the **east** and adjust the time until you see the Moon rising.
   a. What time does the Moon rise?
   b. Press the semicolon ";" key to turn on the meridian line. What time does the Moon cross the meridian?
   c. What time does it set?
3. If you were taking a picture of the Moon in the daytime, what is the range of times you could take a picture on 23 February 2022?
4. Zoom in on the Moon and look at its shape.
   a. What is its phase on 23 February 2022?
   b. Turn off the ground and center the view on the Moon. Advance the day by opening the Date/Time window, and then clicking the up-arrow (↑) above the day's date, until the Moon is next at first quarter. What is the date?
   c. How can you tell whether a "half-lit" Moon is in the first or third quarter?
5. On this new date,
   a. What time does the Moon rise?
   b. What time does the Moon cross the meridian?
   c. What time does it set?
6. Advance the date by 1 day. What time does the Moon rise? Cross the meridian? Set on this date?
   a. What is the Moon's phase?
   b. What time does the Moon rise?
   c. What time does the Moon cross the meridian?
   d. What time does it set?
   e. What are the differences from Part (6)?
7. Keeping the same time, change your location to Australia (hit **F6** and click on Australia in the location window). What phase is the Moon in?
8. Now, change your location to the Moon and look back at the Earth (search for and select "Moon" in the Location window). What phase is the Earth in?

3.1.4 Lab Quiz on Moodle

Go to the Lab 4 section on the Moodle page and complete the End-of-Lab Quiz.

4 Lab 5: Motions of the Sun

4.1 Worksheet

1. The Sun's Position at Noon

In groups of 2-3, follow along the steps demonstrated by the instructor.

a. Set up Stellarium

   i. Open the Location window and set the location to Amherst Center.

   ii. Open the Sky and Viewing Options window.

      a) Under the "Sky" tab,

         1) Set "Stars Absolute Scale" to 0.0 (or the lowest it will go)

         2) Uncheck "Show Atmosphere"

         3) Under "Projection", select "Cylinder"

      b) Under the "Markings" tab,

         1) Check "Azimuthal Grid"

         2) Check "Meridian"

   iii. Zoom all the way out while staying centered on the South horizon point.

   iv. Open Date/Time window and change the date to 21 September.

   v. Find the time (to within a few minutes) when the Sun is crossing the meridian (azimuth $0°00'$ or $180°00'$, running from due north to due south). What time is it? What might cause it to **not** be 12:00 noon?

b. Plot the **altitude** of the Sun as it **crosses the meridian** on the 21st of each month throughout the year.

4.1.1 The Sun's Path during the Day

Watch the Sun's path across the sky on 21 June and 21 December (the summer and winter solstices) over the whole day. On these dates, the Sun reaches its extreme north and south positions respectively. You can advance time faster or slower (or reverse it) using the and buttons in the bottom menu bar, or by **pressing the L and J keys**. Discuss what you see in your groups and answer the following questions:

a. The Sun does not always set due west! What azimuth range do you see it setting over?

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b. The Sun doesn't approach the horizon going straight down! Sketch what you see in Stellarium. Is the angle the same at both solstices?

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c. What is the Sun's azimuth at sunset on the equinoxes (22 September and 20 March)? (If there is "landscape" in the way, look for when the Sun's altitude is near zero.)

d. Suppose there are mountains rising to an altitude of 10° to the west. How would that affect the azimuth of sunset (when the Sun passes behind the landscape, including mountains) on the equinox?

4.1.2 The Sun's Position at Different Latitudes

Work in pairs and have one person do each part. Then, plot the Sun's noontime altitude throughout the year for both parts in the grid. (Make sure to record the values for the quiz.)

Note: when seen from the southern hemisphere, the Sun crosses the meridian in the **northern** sky!

City	Latitude	Sun max. altitude	Month
Pick a city between S 24°–60°:			
Pick a city in the tropics (between N 23° and S 23°):			

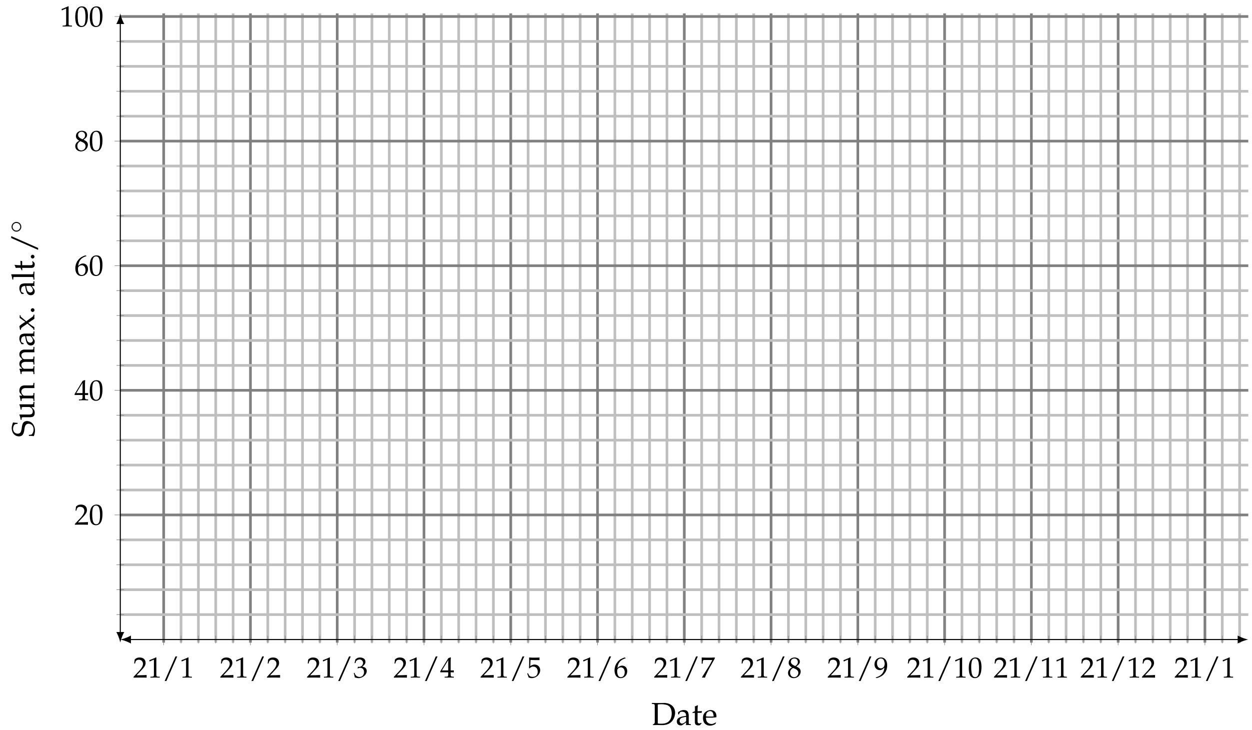
4.1.3 The Sun's Path at Different Latitudes

Now, let's look at how the Sun moves across the sky from different locations on Earth. Follow along with your instructor as below:

Open the Location window and type into the "Latitude" entry "N 66d 30m" (note where the spaces are). You should see the red arrow on the map jump to a location north of Amherst Center. (Leave the longitude unchanged from Amherst Center (W 72°) so the time zone stays the same.)

a. At the Arctic Circle (N 66° 30′) and northward, you can sometimes get 24 hours of daylight, and vice versa. Note how the Sun's path becomes more horizontal closer to the North Pole.

b. At the Equator (N 0°), notice how the Sun moves straight up and down as it approaches the horizon. Why would this make twilight shorter in the tropics?



c. From locations at mid latitudes in the Southern Hemisphere, the Sun approaches the horizon at an opposite angle from what we see, and the Sun spends most of the day in the **northern** sky. Note: Does this mean that the Sun is travelling in the opposite **direction** (east or west)?

4.1.4 Lab Quiz on Moodle

Go to the Lab 5 section on the Moodle page and complete the End-of-Lab Quiz. Note that some of the questions will depend on what city your team picked for part (3), so be sure to enter the correct latitude of that city.

5 Lab 6: Solar Power

5.1 Worksheet

You will be working in groups at each table to carry out 2 experiments. For these experiments you have:

1. A flashlight
2. A metre stick
3. A protractor

First, decide on your roles in the experiments, e.g., experimentalist, note taker, calculations, number checker, graphing, etc. Once you've decided as a team, write down your members and roles on the Lab 6 Table Worksheet.

5.1.1 Power vs. Distance

In this experiment, you will measure how distance and angle affect the amount of sunlight, and corresponding energy, that falls on the ground.

1. For this experiment, push the sleeve on the front part of the flashlight all the way **in**, i.e., to make the total length of the flashlight as **short** as possible.

2. Shine it on the white board from 0.5 ft. As a group, find and agree on the position of the edge of the beam.

   N.B.: it may be faint and somewhat confusing because of reflections inside the flashlight.

3. Next you will shine the flashlight on the white board and measure the area of the circle from several different distances. Make measurements of a and **b** (should be approximately the same) with the light bulb at 0.5, 1, 1.5, and 2 meters. *The idea here is the flashlight at 1 meter is analogous to sunlight at 1 AU. Earth's distance varies just slightly throughout its orbit, between 0.983 and 1.017 AU, less than a 2% variation. Mars on the other hand is about 50% farther from the Sun (and its distance varies by 10%), and Venus about 30% closer to the Sun (and its distance varies by ¡1%). From your graph you can see how the intensity of sunlight varies with distance.*

4. Fill in a and b in the table then carry out the calculations to find the area the light is spread over. To simplify the calculations a bit, we will imagine that the flashlight produces 10,000 watts of light output. What we want you to determine is the number of watts per square centimeter at each distance. The *area* of your beam equals $0.79ab$. Measure a and b in centimeters to find the area in square centimeters, and then calculate 10,000 watts/*area* to find the watts per square centimeter. (Fill in the table.)

5. Plot you results versus the distance between the board and the flashlight's light bulb. Pick one other distance to fill in a gap in your graph or to check one of the first measurements if it seems inconsistent with the others.

5.1.2 Power vs. Angle

You will next repeat the previous experiment, but now you will measure the effect of changing the angle while keeping the flashlight bulb at a constant distance of 1 meter from the whiteboard. *This models what happens on different parts of Earth's surface while the Sun is shining on the ground at an angle. (Mar's axis is tilted a little more than Earth's and is highly variable, while Venus's is very small, just a few degrees, but it spins backward.)*

a. Change your role in this experiment, and write down your new role on the table worksheet.

b. This time you will use the meter stick to keep the flashlight's light bulb at a fixed distance of 1 meter from the board, and a protractor to measure the angle. Note that you can use markers to outline the dimensions a and b of the ellipse created by the flashlight. Try to keep the ellipse of the beam centered on the base of the meter stick so b stays about the same.

c. You will calculate the area of the beam for several angles. In addition to 90, which you can copy over from the first experiment. Make measurements at 71, 47, and 24. These correspond to the altitude of the Sun in Amherst at noon on the summer solstice, the equinoxes, and the winter solstice respectively.

d. As before, divide 10,000 watts by the area you measured at each angle, determine your y-axis scale, and fill in the table with your measurements and calculations and graph the data.

e. From your graph, at what angle does the intensity of light match the intensity at 1.5m (50% farther away)? Try to estimate that angle then carry out one last measurement at that angle and fill it in the your table.

5.1.3 Distance vs. Angle

The angle you measure relative to the whiteboard is like the "altitude" of the Sun. So when the flashlight is shining straight at the board, it is like having the Sun at the zenith, 90 from the horizon.

At noon on the winter solstice in Amherst the Sun has an altitude of about 24. Compare your graphs to estimate the distance at which the watts per square centimeter (at 90) is the same as the watts per square centimeter at an angle of 24. **What distance do you estimate matches the light intensity at 24? __________ (record this for the end-of-lab quiz)**

5.1.4 Lab Quiz on Moodle

Go to the Lab 6 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

5.2 Table worksheet

6 Lab 7: Calendars, Horoscopes, and Precession

6.1 Worksheet

7 Lab 8: Motions of the Planets in the Sky

7.1 Worksheet

8 Lab 9: The HR Diagram

8.1 Worksheet

8.1.1 Stellar Properties

In groups of 2-3, grab a computer. Start up *Stellarium*, and put yourself in Amherst. Search for the star *Procyon*, and if necessary adjust the time until it is above the horizon, then work *carefully* through the following together.

Note: It is easier to find the data we need in Stellarium if you limited the information it displays. Open up the configuration window (F2), then click the information tab and click "None" at the top. Select the following to display: Name, Catalog number, Visual magnitude, Absolute magnitude, Distance, and Additional information.

a. What is the star's magnitude? What is its absolute magnitude? Why do these differ?

   A reminder of magnitude scale is shown below. ADD IMAGE

b. Fill in the first 5 columns below using the information in Stellarium:

8.1.2 Stellar Sizes

Start up a web browser, and go to the following address (or click on the link in Moodle): **http://astronomy.nmsu.edu/geas/labs/hrde/hrd_explorer.html** Under **Options**, change the x-axis scale to "**B-V color index**" and the y-axis scale to "**magnitude**," and **check** all but "Instability Strip" box. This shows an interactive "Hertzsprung-Russell Diagram" that helps us to examine the properties of stars.

a. **Adjust the Temperature slider** so that the red arrow on the bottom axis of the graph matches the star's B-V color value. Enter the star's temperature in the table.

b. **Adjust the Luminosity Slider** so the red arrow on the left axis of the graph matches the star's absolute magnitude. The program calculates the star's luminosity in solar luminosities (L). Enter the star's luminosity value above.

c. ***With both the Temperature and Luminosity sliders*** set to the values you just found, the program calculates the star's radius in solar radii (R)-in other words, how many times larger or smaller than the star is. Enter the value in the table. This tells you how many times bigger the star's diameter is than the Sun's diameter.

d. Which region does your star fall closest to in the H-R diagram?

8.1.3 The Stars We See

In *Stellarium* turn on constellation boundaries (B) and labels (V). Each table will be assigned a constellation: : 1 Botes, 2 Canis Major, 3 Cassiopeia, 4 Centaurus, 5 Cygnus, 6 Lyra, 7 Orion, 8 Sagittarius, 9 Scorpius, 10 Ursa Minor, 11 Virgo.

a. Find the temperature, radii, and other properties of as many of the brightest stars in your constellation as there are people at your table-break up the work between everyone at the table by writing the names of the stars on your Table worksheet and assigning them to your group members. Write the information for your own star below, and copy this into the Table Worksheet after you have finished.

b. On the whiteboard corresponding to the distance of your star, draw a circle to represent your star. The circle should have a **diameter** in centimeterse equal to the size factor of your star. Use a marker color matching the following scale depending on the spectral type: O, B, A blue; F, G green; K, M red. Write the spectral type of your star next to the star.

8.1.4 Nearby Stars

For this activity you are going to examine nearby stars in your constellation. To find them go to Wikipedia's List of Stars in [Your Constellation] or follow the link in Moodle. Sort the stars in order of distance, and look at the nearest stars, one for each person at your table.

In the H-R Diagram Explorer, change the X-Axis Scale to "spectral type." Now when you adjust the Temperature slider you should get the arrow along the x-axis positioned in your star's spectral type (O,B,A,F,G,K,M) and the arabic numeral (0-9) following that letter indicates where in the range the star lies. For example, the Sun, a G2 star, is toward the left (hotter) side of the range of G-type stars, G0 would be at the left edge, G9 at the right edge.

a. Enter the information for the closest star found at your computer below and copy the information into the Table Worksheet, and compare your results at your table.

b. In the H-R Diagram Explorer web app, and click on "the nearest stars" and "the brightest stars." Why do these look so different?

c. How do the stars you can see by eye at night compare to the Sun?

d. How do the nearby stars compare to the Sun?

e. Is the Sun a "typical" star

8.1.5 Lab Quiz on Moodle

Go to the Lab 9 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

To learn more about the H-R diagram, visit https://sci.esa.int/gaia-stellar-family-portrait/

8.2 Table worksheet

9 Lab 10: Distances of Stars in Space

9.1 Worksheet

9.1.1 Building a Constellation

Each table will construct a 3-dimensional model of a constellation. You will be assigned one of the constellations: Aquila, Bootes, Capricornus, Centaurus, Gemini, Hercules, Leo, Pegassus, Taurus, Virgo. You should select at least as many of the brightest stars in the constellation as you have people at your table. Try to pick stars that let you make out the shape of the constellation.

a. Find your constellation in Stellarium. Then sketch it oriented so that it fills most of the white board. Copy the bright stars of the constellation onto the whiteboard with lines connecting them as in the stick figure version in *Stellarium*. (Tap **C** for constellation lines.)

b. Write the Name, Spectral Type, and Parallax next to each of the stars that you are using on the whiteboard. You can find this information by clicking on each star in *Stellarium*. Add this information to your table worksheet.

c. The table will get a bundle of strings, tape, and clips. While holding the tied end of the bundle of strings about 2 meters from the board at about eye level, tape the free end of each piece of string onto the whiteboard at the position of each star. Adjust the strings so that a gentle pull on the bundle keeps all the strings fairly straight and untangled.

d. Each person should calculate the distance of at least one star in parsecs according the the distance formula:

   distance (in parsecs)=1/parallax (in arc seconds)= __________

   also enter this value on the table worksheet.

e. Each person should select a colored ball for the star whose distance they calculated according to the following scheme:

   (i) Type: O or B-violet; A-blue; F-green; G-yellow; K-orange; M-red.

   (ii) Luminosity class: I-large; II or III-medium; IV or V-small

   If your star has an unusual classification try googling it for more information and choose the closest representation for it that you can. Write down the color and size of the ball you decide best represents your star on the table worksheet.

f. From the point where all the strings are tied together, which represents the position of the Sun, measure out a distance of 1 centimeter per parsec distance of each star and fasten the correct color and size ball in place. If the calculated distance is larger than the length of the string, put the ball at the board and write its distance beside it.

g. **When everything is in place, call over an instructor to check your work.**

9.1.2 Changing Perspective

Examine the stars in your constellation from the position of the Sun. Their pattern should look very similar to the constellation you see in the sky. Go around the room to look at the other constellations.

a. On the scale of the model, about how far apart are your eyes?__________
Move 10 or 20 parsecs to either side of the Sun and sketch the pattern of stars from the new position. How does it compare to the original pattern?
Copy one of your group's better examples to the table worksheet.

b. Which star appears to change position most relative to its original position as you move to the side? ***Discuss this at your table and answer on the table worksheet.***

c. On the scale of your model, how far away from the Sun is Neptune, roughly speaking? Should star pattern change at all? ***Discuss.***

9.1.3 Lab Quiz on Moodle

Go to the Lab 3 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

Extra-credit Moon Project

Try to get a picture of the Moon during the daytime. You can do this from anywhere, and take two pictures one zoomed out so you can see the Moon and the horizon, and the other zoomed in on the Moon. You will need to submit three things:

a. A picture zoomed-out as much as possible showing the horizon and the Moon. (The Moon will look very small in this picture.)

b. A second picture of the Moon zoomed-in as much as possible with your camera.

c. A screen-shot of Stellarium set up to the same location and time as when you took your picture showing the Moon's information at that time.

One of the goals of this project is to learn ***when*** you can see the Moon during the daytime, and ***where*** to look. This changes according to the phase of the Moon. You will also have to plan around the weather. Stellarium can be very helpful in figuring this out. You can also search on the internet for moonrise and moonset times, and then you need to think about where the Moon will be as it goes from east to west.

9.2 Table worksheet

10 Lab 11: Structure of the Local Group

10.1 Worksheet