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.

Contents

0 General

0.1 Syllabus

0.1.1 Class information

Astronomy 100/1 Lab is conducted in tandem with Astronomy 100 and(/or) 101 courses and is required to be taken simultaneously.

The goal of Astronomy 100/1 Lab is to introduce some basic aspects of observational astronomy, and help relate that knowledge to the broader science of astronomy, which the lecture portion of the course focuses on. We will explore many aspects of the day and night sky to learn how objects move over the course of the day, month, and year, and how the patterns of what we see in the sky change from different parts of the Earth. We will also carry out several activities to help explain important ideas in astronomy.

Each semester, 6 independent sections are held on Monday, Wednesday, and Friday of every school week at 12:20-1:10pm (1220-1310) and 1:25-2:15pm (1325-1415). Every section is held in the Integrated Learning Center (ILC) room S220.

To reduce paper wastage, much of the course information is posted on Moodle. Check there regularly for announcements and any schedule changes as well.

0.1.2 Instructors

Course coordinator:	Prof.	@astro.umass.edu
Mon 12:20pm lead TA:		@astro.umass.edu
Mon 1:25pm lead TA:		@astro.umass.edu
Wed 12:20pm lead TA:		@astro.umass.edu
Wed 1:25pm lead TA:		@astro.umass.edu
Fri 12:20pm lead TA:		@astro.umass.edu
Fri 1:25pm lead TA:		@astro.umass.edu

When contacting your section TA or the course coordinator, please remember to put "Astro Lab" in the subject of your email. Most questions can be answered by your section TA. However, also note that Astronomy 100/1 Lab is **distinct** from Astronomy 100/1 lecture, so **the lab TAs cannot help you with questions about the lecture class**.

0.1.3 Grading

The Astronomy Lab total grade makes up 25% of the overall Astronomy 100/1 course grade, and does not have a separate grade. The remaining 75% of the Astronomy 100/1 course grade comes from lecture assignments and exams.

There are 8 labs that together contribute 80% of your overall lab score, and the remaining 20% is from the lab Sunset Project. There are also opportunities for extra credit.

Most of the lab work is done during section, so attendance and participation is critical to your grade. Your lab grade will usually raise your overall course grade **if** you attend lab every week and take all the required photos correctly. However, failure to attend will certainly lower your overall grade.

Grading of each lab is based primarily on participation, which is recorded using Moodle. Hence, please bring a smartphone, tablet, or notebook computer to lab. If you don't have one available, you can log in on one of the computers in class.

Submitting a photo that someone else took is plagiarism under the UMass Academic Honesty Policy, and it will be dealt with accordingly. If you have questions about what is or isn't allowed, please ask your lab instructor.

0.1.4 Attendance and schedule

Table 1: Lab schedule

Week	Month	M	W	F	Lab
1					1
2					1
3					2
4					3
5					4
6					Makeup
7					5
8					6
9					7
10					8
11					9
12					Makeup
13					Break
14					
15					Reading
16					Exams

For the project, you will need access to a digital camera (a cell phone camera is fine). You will take your own original pictures and upload them to Moodle over the course of the semester. Taking the photos is not difficult, but does require some advance planning. We will cover this in detail in Lab 3.

We also advise you to keep your lab worksheets from each week, since we will sometimes refer to them in later labs.

If you must miss a lab at your regularly scheduled time, e.g. if you are ill or have a University-sponsored event:

First, try to make up the lab at one of the other sessions the same week. Look at the lab schedule in Table 1 for a section with the same Lab number, and make sure to email the course coordinator with your proposed switch and reason.

If you can't make it, there will be make-up lab sessions for each lab later in the semester, during make-up weeks, also listed in the schedule. A specific schedule will be released closer to the date. Note that make-up sessions have to accommodate the team-based nature of the labs, so individual make-ups are not possible.

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 the atmosphere visualisation on or off, 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 the ground visualisation on or off, 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 the constellation lines on or off, 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 the constellation names on or off, 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 the constellation art on or off, 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 the stars on or off, 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 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 Moodle Lab Quiz

Go to the section for this lab 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!

2 Angular Sizes on the Sky

2.1 Worksheet

2.1.1 Photo Policy Acknowledgement on Moodle

On Moodle, under the section for this lab, carefully review and respond to the Photo Policy Acknowledgement. **You will not be able to get credit for the other activities OR the lab project until you do!**

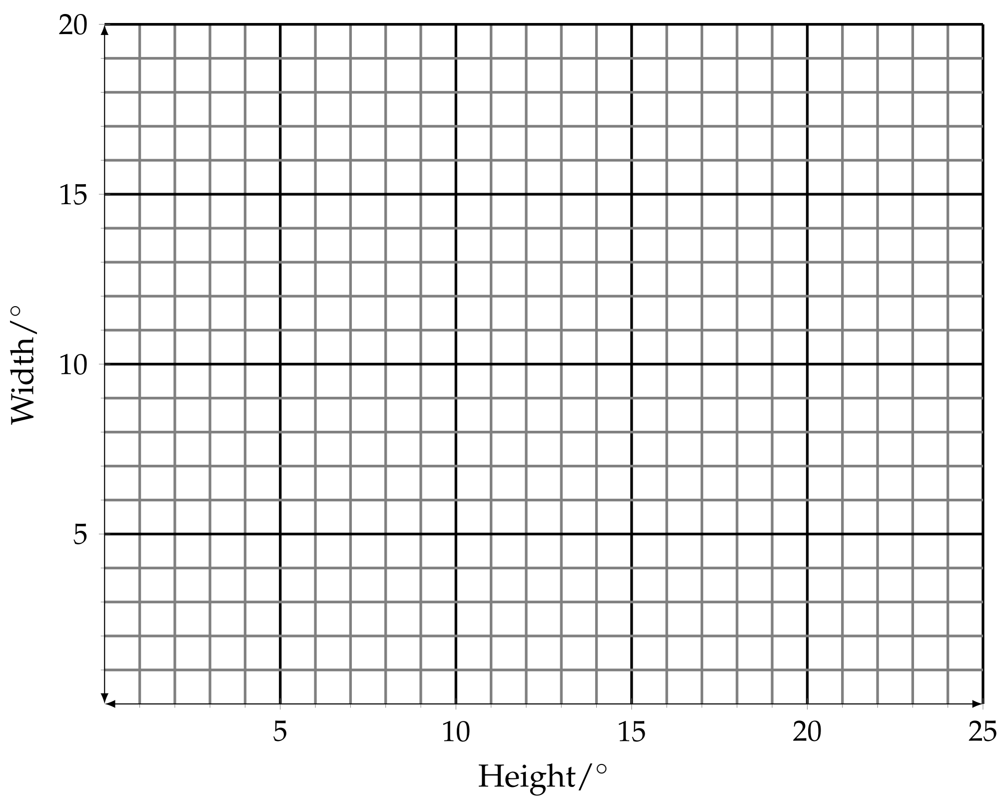
2.1.2 Angular sizes

We will use a uniform grid to get a sense of how to consistently compare the angular sizes we see.

1. Stand with your eye/camera located 12 ft from the screen. Look at the floor plan to determine where you should stand. At this distance, the squares on the grid are 1° wide on each side.

2. Try out things you can use to estimate different angles, e.g., your outstretched hand, your thumb, a credit card, a coin, a key, or even a cell phone that you always have with you. Write down what you use and sketch how they appear on the grid.

   Be consistent! E.g., if you are using 4 fingers at arm's length, always hold them out at full arm's length.



Size	1°	5°	10°	20°
Object				

2.1.3 Calibrating your camera (angular field of view)

At a set zoom level (as well as picture size i.e. height/width ratio), your camera will always cover the same angular dimensions. This is also often known as a **field of view**. Let's find out what they are by calibrating your camera.

1. Hold your camera at the same position as before, i.e. 12 ft from the screen. Make sure your **camera** is located at the 12 ft mark.
2. Zoom in as far as you can on your camera.
3. Take a photo of the grid. Try to align it with the screen.
4. Count the number of squares on each side of your picture. This will give you the angular size of each side.
5. Record all your findings and settings below.

Zoom level	Other settings	Angular size: Height	Angular size: Width

Now let's use what we've learnt to do some astronomy! First, we'll use the visual estimates from the second section.

1. Look at the Stellarium view projected on the screens. It simulates a real-life view of the night sky at the same scale as the grid before.
2. Use similar things to those in Part 1 (fingers, coin, etc.) to estimate angular sizes and answer the questions below. **Remember to be consistent! Hold your arm out at full length!**
   (a) How many degrees is Aldebaran from the Pleiades cluster of stars?

   ____

   (b) Which of your angular measures (such as hand, thumb, pencil) is most similar in angular width as the Pleiades?

   ____

   (c) How many times wider is your outstretched finger than the Moon?

   ____

3. Take a photo of the projected Moon like you did for the grid:
   - Fully zoomed in
   - Held at 12 ft from screen
4. Compare it with your calibration picture and calibrated values. How big is the Moon?

   ____

2.1.4 Taking a zoom back

Now let's calibrate your camera fully zoomed out.

1. Zoom out on your camera to 1x. **If your camera has 0.5x zoom or similar, do not use it.**
2. Take a photo of the grid from 12 ft. You'll see that the screen appears much smaller. Compared to before, when your camera was zoomed in, approximately how many times wider and taller is your camera field of view now? How does this compare to your previously recorded zoom level?

   ____

3. Move your camera approximately 3 ft from the screen using a yardstick.
4. Take a photo of the new grid, which has lines every 5°.
5. Count the number of squares on each side of your picture **and multiply that number by 5**. This will give you the angular size of each side.
6. Record all your findings and settings below.

Zoom level	Other settings	Angular size: Height	Angular size: Width

As you end up standing 4× closer to the screen, the projected grid has cover an area that is 4× taller AND 4× wider in order to be consistent. In general, when you get x times closer to an object, its angular size will get x times bigger.

Now, we'll look at a simulation of a sunset view, similar to the pictures you'll be asked to take for the sunset project.

1. Look at the Stellarium view projected on the screens. It simulates a real-life view shortly before sunset.
2. With your camera 3 ft from the screen, take a photo of the screen.

3. Compare it with your calibration picture and calibrated values to find the following, keeping in mind that the azimuth of due west is 270°.

Azimuth of Sun	
Altitude of Sun	

2.1.5 Moodle Lab Quiz

Go to the section for this lab on the Moodle page and complete the End-of-Lab Quiz and upload your calibration pictures on Moodle by the end of the week. Also, remember to fill out the Photo Policy Acknowledgement.

If you switch to a new camera or change your settings, let your TAs know. There will be opportunities to re-calibrate your camera with the grids in future labs.

3 Angular Size vs. Distance

3.1 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.

3.1.1 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.**

3.1.2 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?

3.1.3 Angular Size of Astronomical Objects

1. Let's consider the Sun.

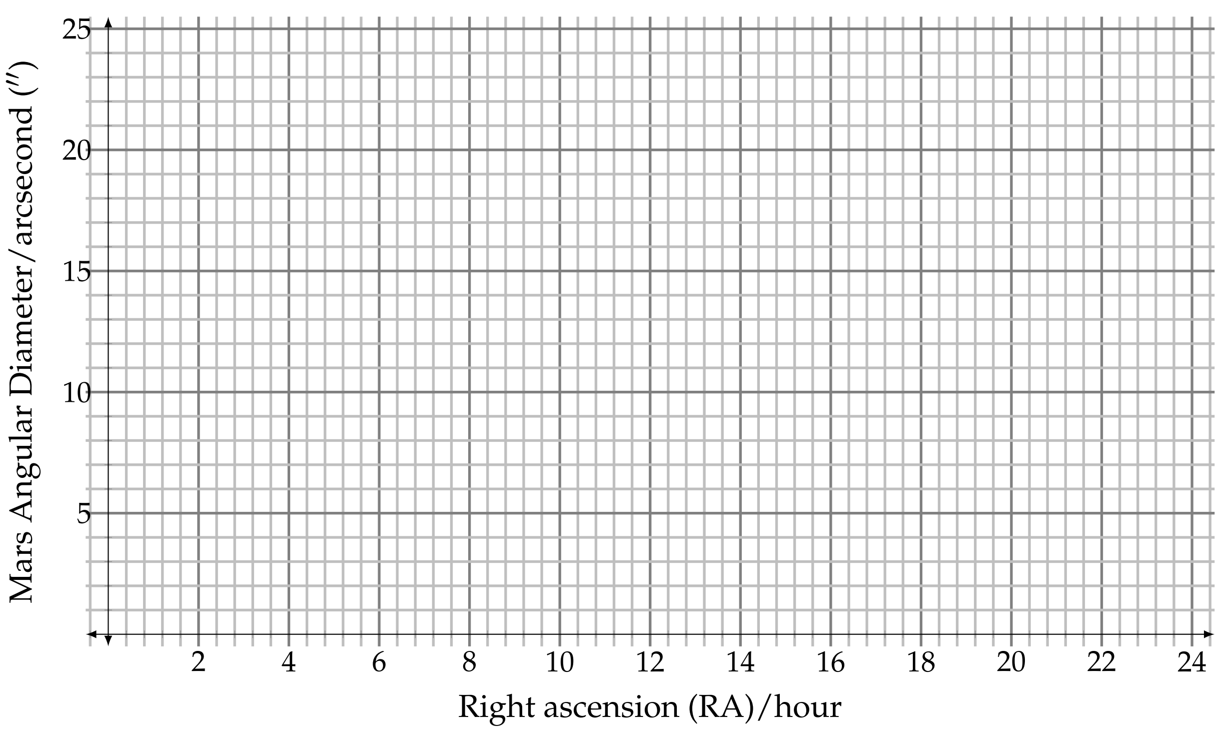
   a. Does the Sun's angular size changes during the year?

   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?

3.1.4 Moodle Lab Quiz

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

3.2 Table worksheet

3.2.1 Table no.

Fill in your section and table number below.

- Section: ________
- Table no.: ________

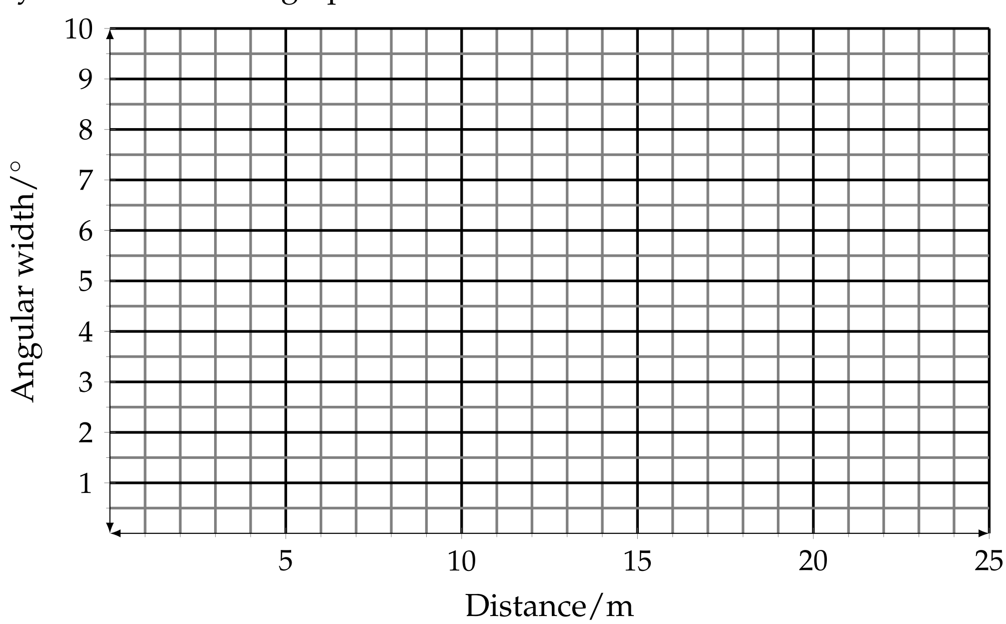
3.2.2 Measurements

Write your name, distance from object, and angular width measurement below.

Name	Distance (m)	Angular width (°)

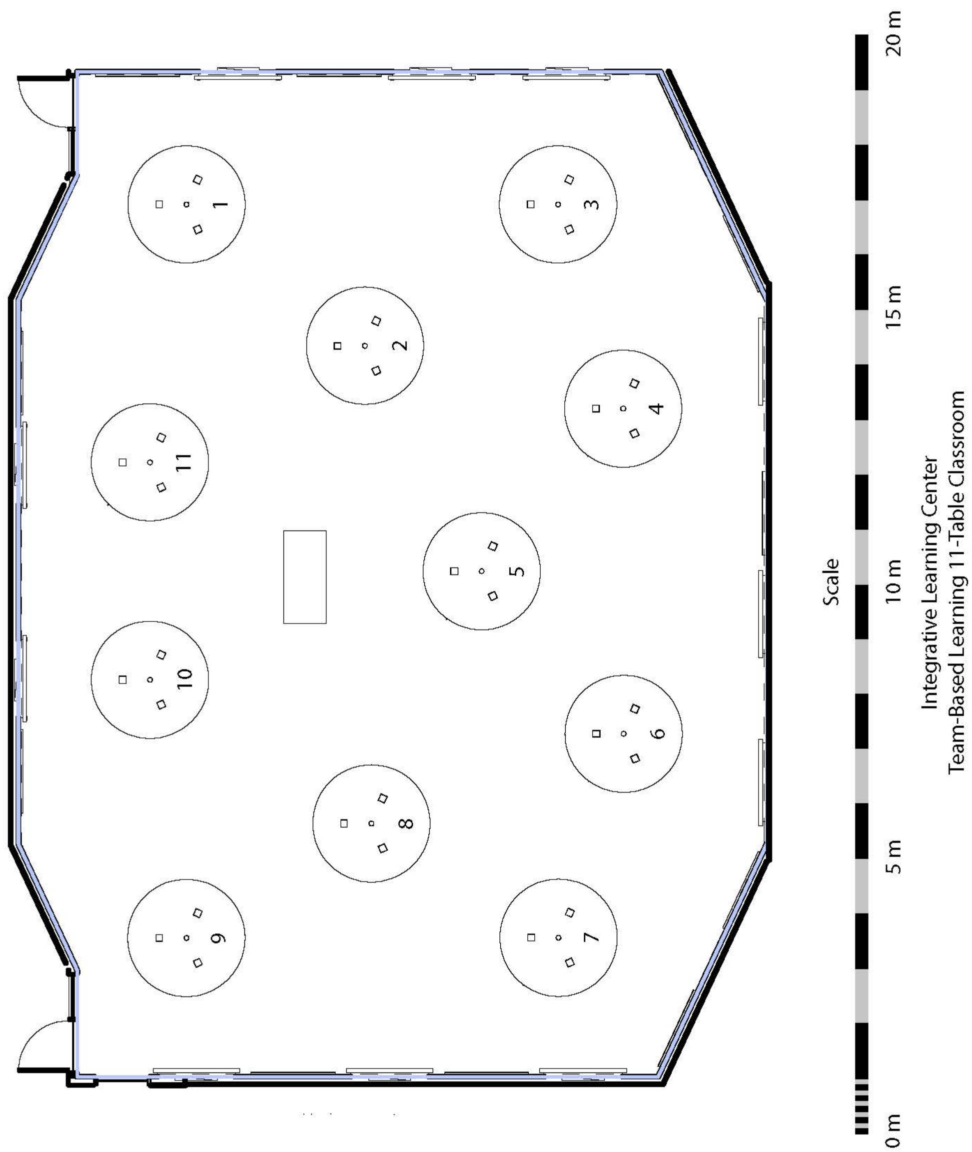
3.2.3 Plot

Plot your results in the graph.



3.2.4 Location diagram

Mark the locations where you took your measurements in the diagram.



4 Phases of the Moon

4.1 Worksheet

4.1.1 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.

4.1.2 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?

4.1.3 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?

4.1.4 Moodle Lab Quiz

Go to the section for this lab on the Moodle page and complete the End-of-Lab Quiz.

5 Motions of the Sun

5.1 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.

5.1.1 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?

   ____

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?

   ____

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?

____

5.1.2 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°):			

5.1.3 The Sun's Path at Different Latitudes

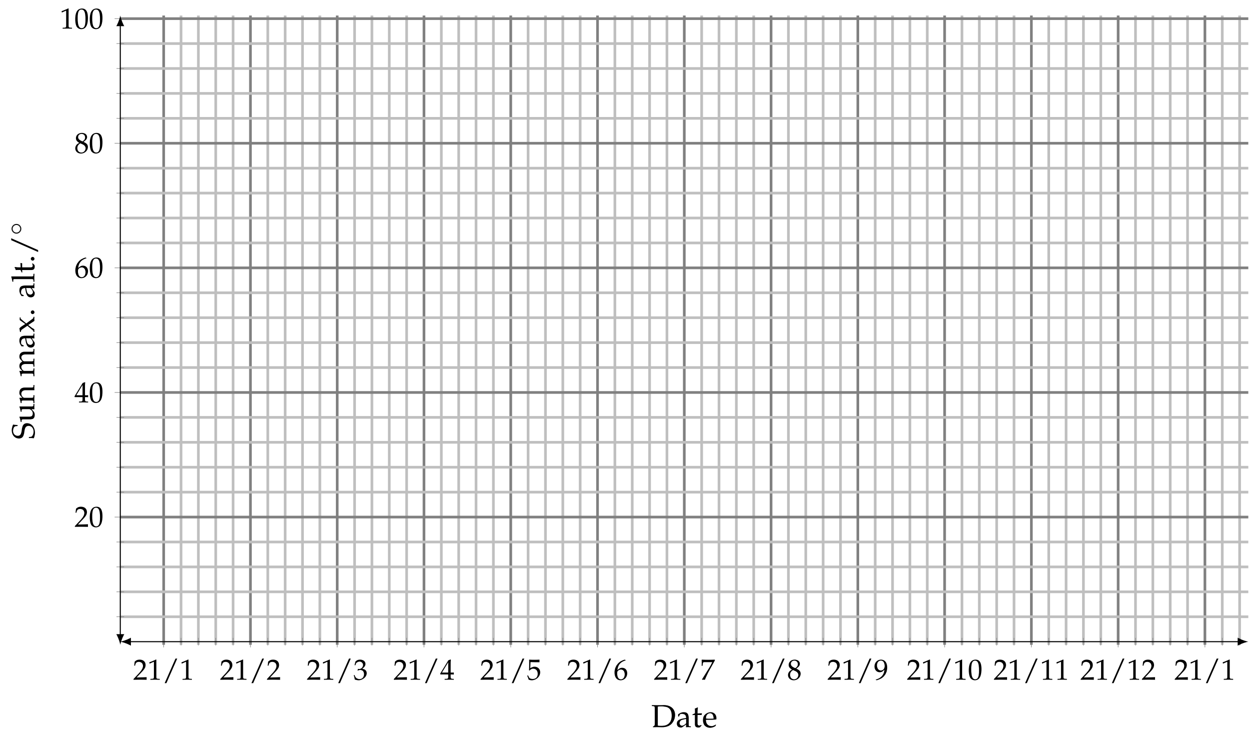
Now, let's look at how the Sun moves across the sky from different locations on Earth. Follow along with your instructor as below:

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)?

___

5.1.4 Moodle Lab Quiz

Go to the section for this lab 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.

6 Solar Power

6.1 Worksheet

As a team at your table, you will 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. Make sure everyone participates in observation at some point in experiment 1 or 2.

N.B.: Be sure to mark your table number on the end-of-lab quiz or you may not receive credit!

6.1.1 Power vs. Distance

In this experiment, you will measure how distance and angle affect the intensity 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., make the total length of the flashlight as **short** as possible.

2. Shine it at the whiteboard straight on from 0.5 ft away. As a group, find and agree on the position of the edge of the beam.

   You can use markers to outline the dimensions a and b of the flashlight beam. They should be about the same, i.e., the beam should be circular.

3. Next, shine the flashlight at the whiteboard and measure the height a and width b of the beam from several different distances. Make measurements with the light bulb at 0.5, 1, 1.5, and 2 ft.

4. Fill in a and b in the table. Then, carry out the calculations to find the area the light is spread over, i.e., calculate the number of watts per square centimetre at each distance.

   To simplify the calculations, assume that the flashlight produces 10,000 watts (W) of light output. Measure a and b in centimetres, and then use area $= 0.79\ ab$. Next, calculate 10,000 watts/area to find the intensity in watts per square centimetre.

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

6.1.2 Power vs. Angle

For this experiment, we will measure the effect of changing the angle while keeping the flashlight bulb at a constant distance of 1 ft from the whiteboard.

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

2. For this experiment, pull the sleeve on the front part of the flashlight all the way **out**, i.e., make the total length of the flashlight as **long** as possible.

3. Use the yardstick to keep the flashlight's light bulb at a fixed distance of 1 ft from the board, and use a protractor to measure the angle.

   As before, you can use markers to outline the dimensions a and b of the flashlight beam. It will elongate into an ellipse at smaller angles. Try to keep the ellipse of the beam centered on the base of the yardstick, so the width b stays about the same.

4. Make measurements at 90°, 71°, 47°, and 24°. Assume that these smaller angles correspond to the altitude of the Sun in Amherst at noon on the summer solstice, the equinoxes, and the winter solstice respectively.

   As before, use area $= 0.79\ ab$ to find the area of the flashlight beam.

5. As before, divide 10,000 watts by the area you measured at each angle. Determine your y-axis scale based on the range of values you obtain, and fill in the table with your measurements and calculations. Then, plot the data.

6. From your plot, at what angle does the intensity of light match the intensity at 1.5 ft (50% farther away than 1 ft)? Try to estimate what that angle would be, then carry out one last measurement at that angle and fill it out in your table.

6.1.3 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°. By comparing your graphs, estimate the distance where the light intensity (in watts per square centimetre), shining at 90°, is the same as the light intensity (in watts per square centimetre) at a distance of 1 ft and an angle of 24°.

What is your estimate? ________________________ (Record this for the next section.)

6.1.4 Moodle Lab Quiz

Go to the section for this lab on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet, take a picture of it, and hand it in.

6.2 Table worksheet

6.2.1 Table no.

Fill out your section and table number below.

- Section: ___________
- Table no.: ___________

6.2.2 Experiment roles

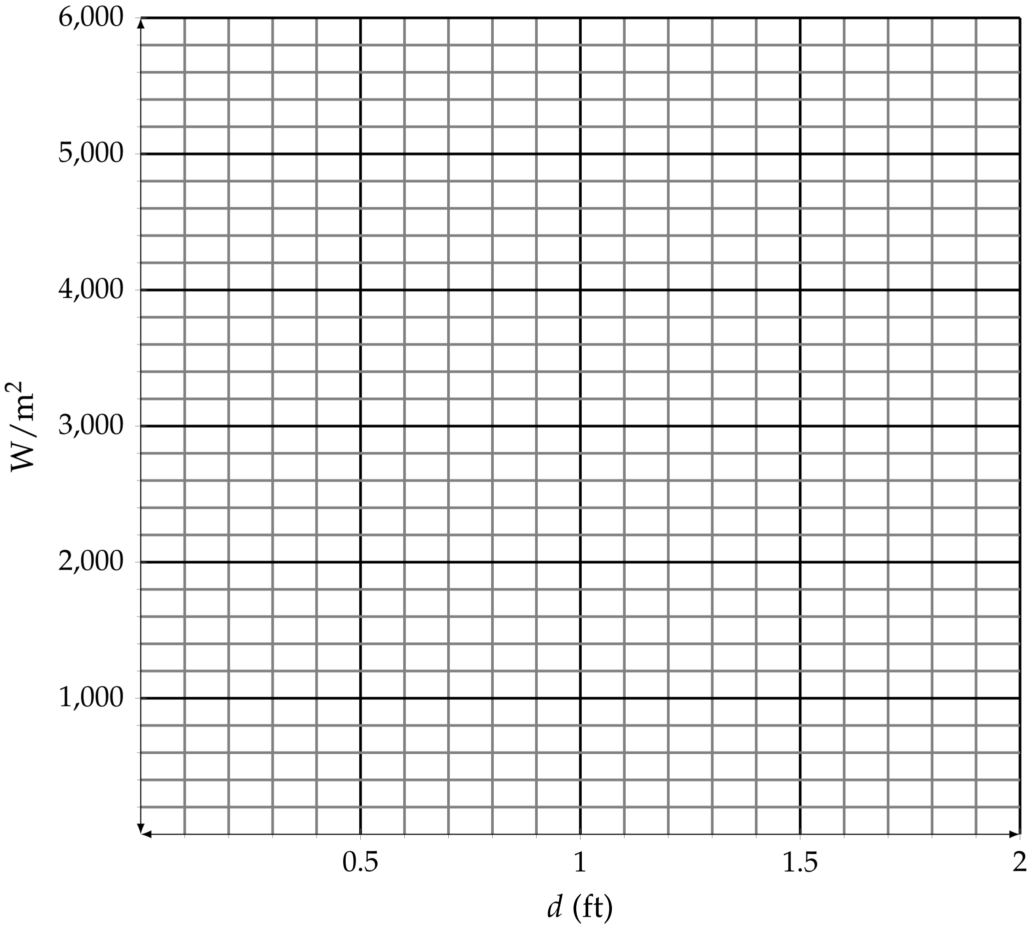
Enter your name and roles for each experiment.

Name	Experiment 1 role	Experiment 2 role

6.2.3 Experiment 1: Intensity vs. Distance

Fill out the table, then plot your data points in the graph. Then, pick another point from which to take another measurement to improve your plot.

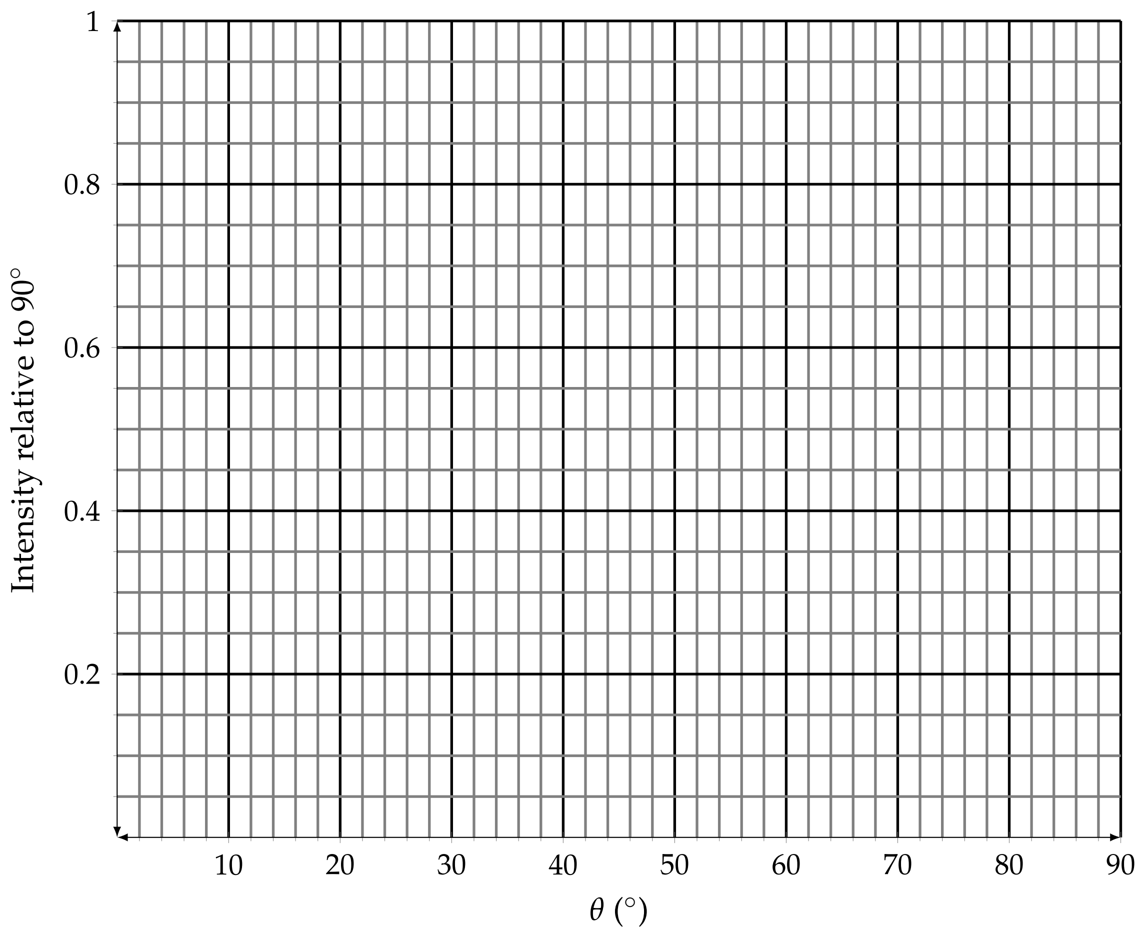
d (ft)	θ (°)	a (m)	b (m)	area (m^2)	400W/area (W/m^2)	area at 1ft/area at d
0.5	90					
1.0	90					1.00
1.5	90					
2.0	90					
	90					



6.2.4 Experiment 2: Intensity vs. Angle

Fill out the table, then plot your data points in the graph. Then, pick another point from which to take another measurement to improve your plot.

d (ft)	θ (°)	a (m)	b (m)	area (m^2)	400W/area (W/m^2)	area at 90°/area at θ
1.0	90					1.00
1.0	71					
1.0	47					
1.0	24					
1.0						



7 Calendars, Horoscopes, and Precession

7.1 Worksheet

7.1.1 Exploring the ecliptic

1. Open Stellarium and set it to your home location. You can also stop time (the pause button in the bottom panel) and set the time to noon.
2. Make the constellations visible.
   (a) Turn off the Atmosphere visualisation.
   (b) Open the Sky and Viewing options window.
   (c) Go to the Starlore tab.
   (d) Under Options, check Show labels and Show boundaries.

1. Find out what constellation the
   (a) Sun
   (b) Moon

   are in today.
2. Click on the Sun and hit the spacebar. This will centre and lock on the Sun.
3. Move forward in time by jumping by day, by holding down the = key.
4. Find out the constellations that the Sun moves through over a year.

What constellations does the Sun move through? What is causing the Sun to move through the stars? What other things change position among the stars as time passes?

7.1.2 What's your sign?

Table 2: Horoscope signs and dates

Sign	Aries	Taurus	Gemini	Cancer	Leo	Virgo	Libra	Scorpio	Sagittarius	Capricorn	Aquarius	Pisces
Start	21 Mar	20 Apr	21 May	21 Jun	23 Jul	23 Aug	23 Sep	23 Oct	22 Nov	22 Dec	20 Jan	19 Feb
End	19 Apr	20 May	20 Jun	22 Jul	22 Aug	22 Sep	22 Oct	21 Nov	21 Dec	19 Jan	18 Feb	20 Mar

1. Shift Stellarium to your birth date. What constellation was the Sun in? Save a screenshot of the Sun's location.

   According to the ancient idea of astrology, this is known as your sun sign or horoscope sign, which somehow determines your characteristics.

2. The dates for each horoscope sign according to modern astrologers is given in the table. What is your sign based on the table?

3. Based on Stellarium, over what range of dates is the Sun actually in the constellation corresponding to your horoscope sign?

4. Set Stellarium to a date in the middle of your horoscope sign. Jump back in time in 500-year blocks until the Sun is actually in the middle of your horoscope sign. How far did you have to go?

   N.B.: To enter a B.C. date, you may need to enter the number first, then put "-" in front.

7.1.3 Precession of Earth's Axis

In fact, the position of the Sun on a particular date shifts steadily through the sky because of the precession of the Earth's axis. Let's visualise this in Stellarium.

1. Jump back to today and turn on the equatorial (NOT azimuthal!) grid.

2. Look at the North celestial pole. Which star is nearest to it? Which star was nearest to it when horoscopes were aligned with the zodiacal constellations?

3. Find the star Vega. Jump back in time in 1000-year blocks. When was Vega the North star?

4. Jump forward in time in 1000-year blocks. When will Vega be the North star again?

7.1.4 Constellations in Other Cultures

Different cultures have come up with different groupings of stars and different stories associated with them. Let's explore them!

1. Go back to your birth date.

2. Pick constellations from another culture.

   (a) Go to Sky and viewing options and go to the Starlore tab.

   (b) Choose another cultural constellation system (other than Western). Which constellation is the Sun in?

If no labelled constellation is available, do some research online and tell us about what you find.

On Moodle, write about the culture you chose and what you've learnt about the constellation.

7.1.5 The Motion of Mars

The planets move through the stars of the zodiac and show some surprising motions, like Mars.

1. Centre your view on Pisces.
   (a) Set Stellarium to 1 June 2020.
   (b) Turn off the atmosphere and ground visualisations.
   (c) Switch to the equatorial axis. (This is NOT the same as turning on the equatorial grid!)
   (d) In Sky and viewing options, turn on constellation lines and labels as before.
   (e) Centre and zoom in on Pisces.
2. Find Mars on the sky.
3. Plot the position of Mars every month for one year (i.e. once a month from June 2020 to June 2021).
4. Connect the points. How many days was it moving backwards (retrograde)?
5. Go back through the same period. This time, zoom in on Mars and take note of its magnitude, phase, and size.
6. Note the highest and lowest magnitudes and note them on the chart.

   Note that the lower or more negative the magnitude, the brighter an object is. The magnitude scale is logarithmic: 5 magnitudes lower is $100\times$ brighter.
7. Repeat for all the planets. Do they all go retrograde (i.e. move backwards for some time)?

7.1.6 Moodle Lab Quiz

Go to the section for this lab on the Moodle page and complete the End-of-Lab Quiz.

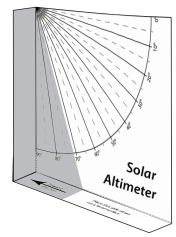
8 Motions of the Planets in the Sky

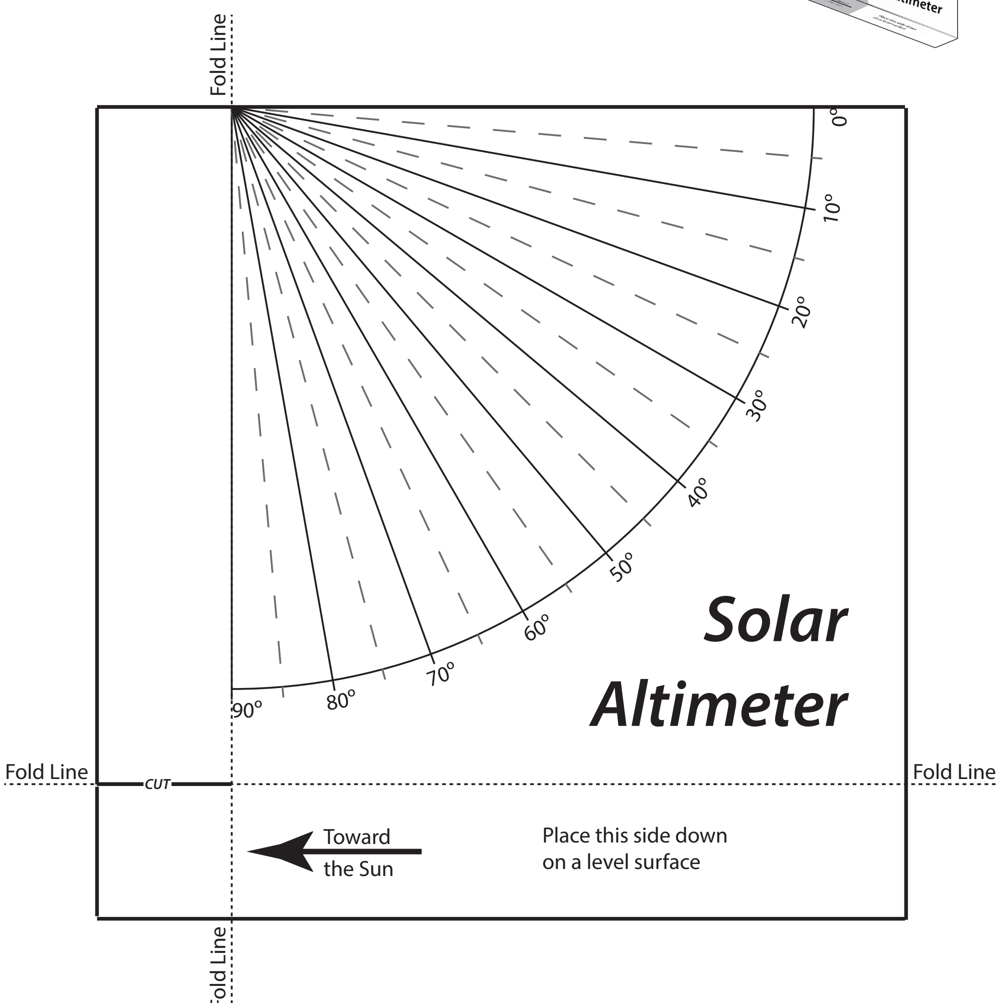
8.1 Worksheet

8.1.1 Solar altimeter

Instructions:

1. Make straight folds along each of the two dotted lines, then flatten back down
2. Cut along heavy outer lines and the notch along the lower fold
3. Refold the two flaps at right angles toward the printed side
4. Tape the bottom left tab to make everything square as shown at right
5. With bottom flap on a flat surface and vertical flap toward Sun, the Sun's shadow will indicate its altitude--about 72° in illustration
6. For greater stability, you may want to tape the bottom to a heavier object





9 The HR Diagram

9.1 Worksheet

9.1.1 Stellar Properties

1. In groups of up to 3, open up Stellarium and turn off atmosphere (A) and ground (G) visualization.
2. Find the star Procyon. From the information panel, find:
   (a) Absolute magnitude
   (b) Color index (B-V)
   (c) Distance
   (d) Spectral type

N.B.: It's a lot easier to find this info in Stellarium if you Configure (F2) the Information to show just what you need. 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. (If you use the web app, you will need to look up Procyon on Wikipedia and look in the information panel on the right side of its page.)

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

____

b. Fill in the first 5 columns in the table using the information in Stellarium.

Name	Absolute Magnitude	B-V	Distance (light-years)	Spectral Type	Temperature (K)	Luminosity (× solar)	Size (× solar)	Location in HRD
Procyon								
(bright)								
(close)								

9.1.2 Stellar Sizes

We'll explore stellar properties using an interactive Hertzsprung-Russell (HR) diagram.

1. Start up a web browser, and go to this website (or click on the link in Moodle): `http://astronomy.nmsu.edu/geas/labs/hrde/hrd_explorer.html`
2. Under Plot Labels:

   (a) Set the x-axis scale to "B-V color index"
   (b) Set the y-axis scale to "magnitude"

3. Click on the HR diagram where Procyon is located by its absolute magnitude and B-V value.

4. 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.

5. 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 in the table.

6. With 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 bigger the star's diameter is than the Sun's diameter. Enter the star's **size** value in the table.

7. Turn on the Main sequence and luminosity classes by clicking them.

8. Which region is Procyon located closest to: Main Sequence line (MS), red giants (RG), supergiants (SG), or white dwarfs (WD)?

9.1.3 The Stars We See

Let's examine a sample of bright stars.

O/B	A	F	G	K	M
Violet	Blue	Green	Yellow	Orange	Red

1. Return to Stellarium and turn on constellation labels (V) and boundaries (B).

2. In your assigned constellation, find the bright stars and pick one each. Then, find their properties and fill them in the table as before. (If you are using the web app, use Wikipedia.)

3. Fill in the properties of your star on your table worksheet too.

4. Time to *draw* on your art talents! On a blank piece of paper, draw circles representing your stars where:
   (a) the diameter corresponds to its size (1 cm for the Sun)
   (b) the colour corresponds to its spectral type according to Table 9.1.3
   (c) they are labelled with their name and spectral type.

5. On the whiteboard corresponding to the distance of your star, draw a circle to represent your star similar as above. Write the spectral type of your star next to it.

9.1.4 Nearby Stars

Now we'll look at closest stars instead of brightest stars.

1. Go to the Wikipedia page "List of stars in [your constellation]".
2. Sort by distance by clicking the up/down arrows in the Distance column.
3. Pick a different nearest star each and find its properties.
4. On the HR Diagram Explorer page, change the X-Axis Scale to "Spectral type".
5. As before, adjust the Temperature slider so that the red arrow on the bottom axis of the graph matches the star's B-V color value. The red arrow should now also point to your star's spectral type (O,B,A,F,G,K,M). The arabic numeral (0-9) following that letter indicates where in the range the star lies, with 0 towards the left (hotter) edge and 9 towards the right (cooler) edge.

   The Sun is a G2 star. Where on the diagram would it be located?
6. Copy your answers into your table and the table worksheet. Compare your answers.

Answer the following questions.

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

   ____

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

   ____

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

   ____

4. Is the Sun a "typical" star?

   ____

9.1.5 Moodle Lab Quiz

Go to the section for this lab 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/`

9.2 Table worksheet

9.2.1 Table no.

Fill in your section and table number below.

- Section: ________
- Table no.: ________

9.2.2 Constellation assignment

Your table's assigned constellation is: ____________________

Fill in your names below.

9.2.3 Bright stars data

Name	Absolute Magnitude	B-V	Distance (light-years)	Spectral Type	Temperature (K)	Luminosity (× solar)	Size (× solar)	Location in HRD

9.2.4 Nearest stars data

Name	Absolute Magnitude	B-V	Distance (light-years)	Spectral Type	Temperature (K)	Luminosity (× solar)	Size (× solar)	Location in HRD

10 Distances of Stars in Space

10.1 Worksheet

10.1.1 Building a Constellation

Working in teams at your table, your mission is to construct a 3-D model of your assigned constellation.

1. Using Stellarium as reference, sketch your constellation on the white board, marking out the bright stars and constellation lines (lines connecting them like a stick figure). Try to make it fill up as much of the whiteboard as possible. (To show constellation lines in Stellarium, press C.)

2. In Stellarium, click on your assigned stars. Write the Name, Spectral Type, and Parallax of the star next to it on the whiteboard, and also on the table worksheet.

3. Keep the tip of the metal pole (with attached strings) about 6 ft/2 metres from the whiteboard, and at a height of about eye level or centred to your whiteboard sketch. Gently stretch a string to each assigned star and tape the end to the board, making sure that the strings are straight and untangled.

4. Calculate the distance of your assigned star in parsecs using the following distance formula:

   $$\text{distance (in parsecs)} = 1/\text{parallax (in arc seconds)} = \underline{\hspace{3cm}}$$

   Copy this onto the table worksheet.

5. Pick a coloured ball that represents your assigned star according to the following:

Type:	O/B	A	F	G	K	M
Colour:	Violet	Blue	Green	Yellow	Orange	Red

Luminosity class:	I	II/III	IV/V
Size:	Large	Medium	Small

   Write down the colour and size of the ball you picked on the table worksheet.

   If your star has an unusual classification, try looking it up on Wikipedia for more information, and choose the closest representation you can for it.

6. Take the tip of the metal pole (where all the strings are tied together) to represent the position of the Sun. Taking 1 centimetre to represent 1 parsec, measure out distance of your assigned star from the “Sun” and clip in place your “star”. If the calculated distance is larger than the length of the string, clip your “star” right at the board and write its distance beside it.

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

10.1.2 Changing Perspective

1. 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.

   You can also go around the room to look at the other constellations.

2. On the scale of the model (1 cm = 1 parsec), 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?

Original	_____ pc away

   Pick an example in your group to copy onto the table worksheet.

3. Discuss and answer on the table worksheet: Which star appears to change position most relative to its original position as you move to the side?

4. Discuss: On the scale of your model, how far away from the Sun is Neptune? Should the constellations change when viewed from Neptune?

10.1.3 Moodle Lab Quiz

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

10.2 Table worksheet

10.2.1 Table no.

Fill in your section and table number below.

- Section: ________
- Table no.: ________

10.2.2 Constellation assignment

Your table's assigned constellation is: ____________________

Fill in your names below.

10.2.3 Star data

Fill in the data for your stars below.

Name	Spectral type	Luminosity class	Ball colour	Ball size	Parallax (arcsec)	Distance (parsecs)

10.2.4 Constellation sketch

Sketch your constellation below and mark the stars you included in the table.

Original	_____ pc away

Which star appears to shift most when you view the constellation 10-20 parsecs from the Sun?

____

11 Structure of the Local Group

11.1 Worksheet

11.1.1 Sizes of Local Group galaxies

Like we did for constellations last week, we'll work in pairs and then as a class to construct a scale model of the Local Group, the small cluster of galaxies which the Milky Way is a member of.

Astronomers have determined the distances to the galaxies in our neighbourhood through a variety of methods. We have also measured their angular sizes, which we will use to estimate their actual sizes.

1. Working in pairs, go to the Galaxy Data Sign-up link for this lab on Moodle and fill out your names at the next available galaxy.

2. Using a scale of 1 m for 500,000 light-years (2 m for 1 million (1,000,000) ly), have one person stand at a distance from the whiteboard corresponding to the galaxy distance.

3. Have the other person stand at the whiteboard and mark out a width that corresponds to 2° of angular width, as seen by the first person. (This is about the width of your thumbnail with your arm fully extended in front of you.)

   Record this width in centimetres: __________

   If your galaxy is at a distance that is too close for you to be able to stretch out your arm fully, move 3 times farther from the board, and then divide your final size by 3.

4. Trade places and repeat, then average your results.

5. Using this scale, mark out the size of your galaxy as estimated from its observed angular size α, e.g. if your galaxy is 0.1° across, it extends 0.1/2 of the width you have marked out. Use the following formula:

$$\frac{\alpha}{2^\circ} \times \text{width in centimetres} = \underline{\hspace{3cm}}\ \text{cm}$$

   At this scale, the Milky Way, which has a diameter of about 90,000 ly, is about 18 cm in diameter.

6. Using the same scale of 500,000 light-years per 1 m, i.e. 5,000 light-years per 1 cm, estimate the true size of your galaxy. Fill out the data for your galaxy below.

No.	Galaxy Name	Distance (light-years)	Angular diameter ($\alpha/^\circ$)	Diameter (light-years)

E/Sph	S (a-m)	Irr
Yellow	Green	Blue

7. Using colours to denote galaxy type according to the table, make a model of your galaxy as follows.

   If your galaxy is small enough to fit on a small piece of paper, draw it as a circle of the correct size and colour it in with the right colour. If not, get a piece of paper of the right colour and cut out a circle of the correct size to attach to your paper.

The colours also simulate how the galaxies appear. E (elliptical)/Sph (spherical) galaxies, mostly dwarf (dE, dSph), mostly have older yellow stars. S (spiral) galaxies have older yellow stars in the center and star formation making newer, bluer stars in the disk. Irr (irregular) galaxies usually have lots of star formation, which makes new, bluer stars.

11.1.2 Positions of Local Group galaxies

Galaxies in the Local Group mostly lie on a fairly flat plane, so we have assigned them an azimuth according to the direction they lie from the Milky Way. Now, we'll model their positions in space.

1. Your galaxy has an azimuth associated with it. Find the direction of your galaxy relative to the Milky Way. Use the position of the Milky Way we have put up and azimuth values we have marked.

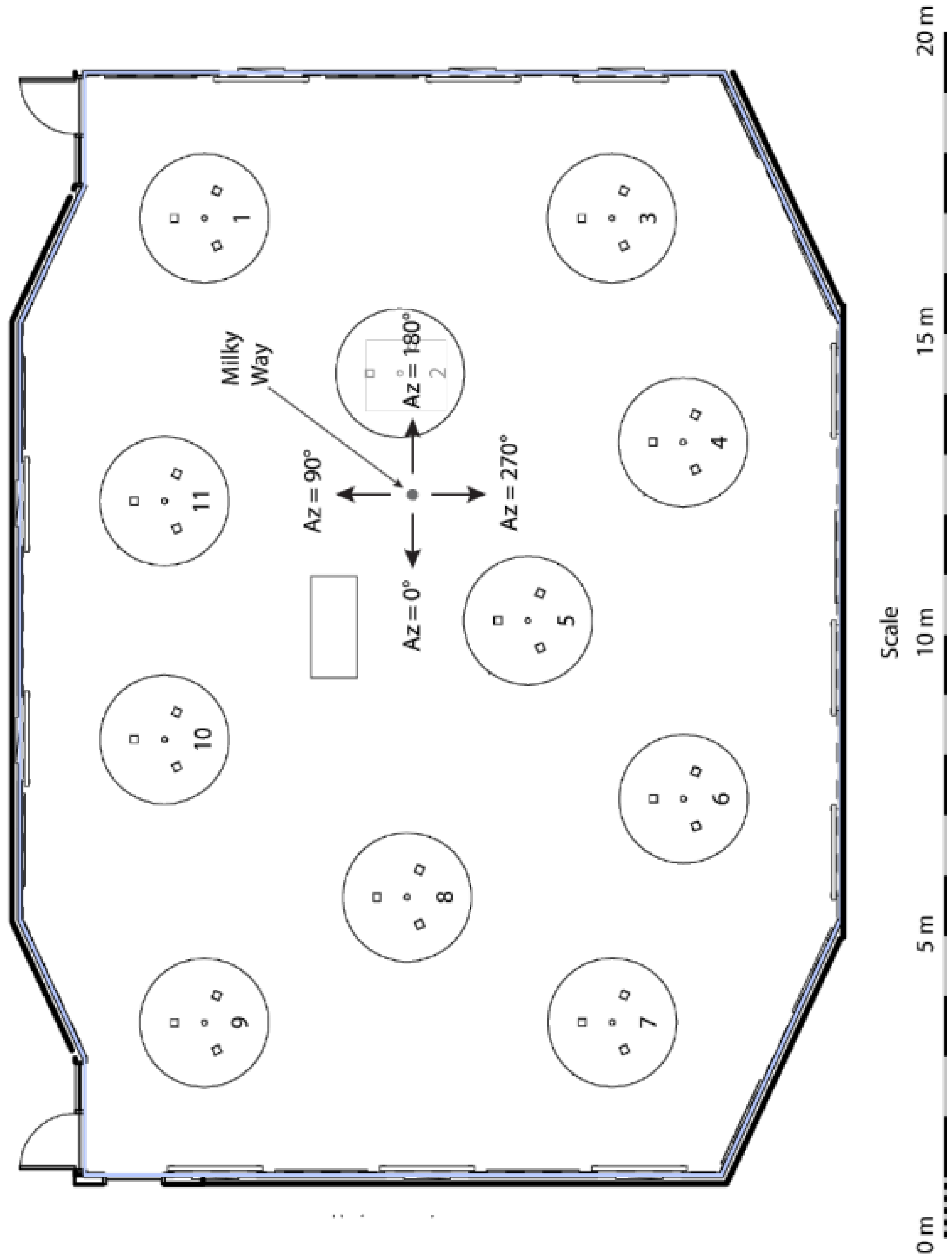
2. In that direction, go out the corresponding distance of your galaxy from the Milky Way, and put it down. Remember that the scale is 500,000 light-years per metre.

3. Mark the position in the diagram.

11.1.3 Moodle Lab Quiz

Go to the section for this lab on the Moodle page and complete the End-of-Lab Quiz.

Be sure to complete the post-lab survey on Moodle before the deadline. Credit is awarded only for completion, not for correctness.



1
2
3
4
5
6
7
8
9
10
11
Milky Way
Az = 180°
Az = 90°
Az = 270°
Az = 0°
Scale
0 m
5 m
10 m
15 m
20 m

12 Project: Movement of the Sunset

12.1 Worksheet

12.1.1 Project overview

For the project, you will be submitting the following:

1. With Lab 2:
   (a) Photo Policy Acknowledgement
   (b) Camera calibration grid photos
2. Project 1st part:
   (a) 1st sunset(/sunrise) photo
   (b) Location documentation photo(s)/information
3. Project 2nd part:
   (a) 2nd sunset(/sunrise) photo
   (b) 3rd sunset(/sunrise) photo
   (c) Annotated photo
   (d) Stellarium screenshots
   (e) Project report

DO NOT WAIT TO TAKE YOUR PHOTOS! The 3rd photo must be at least 4 weeks after the 1st, so if you leave the project to the last minute, you **will** lose points.

12.1.2 Photo Policy Acknowledgement

Make sure you read through the Photo Policy and submit your acknowledgement. Otherwise, you will not get credit for any of your submissions.

Submitting work or pictures that are not your own, or having someone else do it for you, is a violation of academic integrity and will be dealt with harshly.

12.1.3 Camera calibration grid photos

As part of Lab 2, submit photos of the zoomed-in and zoomed-out calibration grids.

The purpose of the activity is to help you work out the angular field of view of your camera, which you will make use of in the project. Hence, it is important that you use the **same** camera for all the sunset(/sunrise) photos, and to do the calibration. If this is not possible, let us know **as soon as you can**.

12.1.4 Sunset photos

The goal of the project is to obtain 3 pictures of the sunset OR sunrise from the exact same location, spaced apart in time. It is important that all 3 photos are consistent, i.e. they must EITHER be of the sunset OR the sunrise, not a mix. If this is not possible, let us know **as soon as you can**.

When you take the picture, ensure that:

1. your camera is zoomed out to zoom factor 1 (if your camera has a wide-angle function that can zoom out to a value lower than 1, e.g. 0.7 or similar, **do not use it**)
2. the Sun is within about 5° in altitude of the horizon
3. the Sun's azimuth can be clearly discerned. Refer to the lecture during lab for examples of acceptable and unacceptable photos.

Don't delete failed pictures! You can still get partial credit for attempts.

For the submission of the 1st part of the project, submit the 1st sunset(/sunrise) photo, along with documentation of the location you took it from.

For the other photos in the project, you must take them from the exact same location. The 2nd photo must be at least 1 week after the 1st photo, and the 3rd photo must be at least 4 weeks after the 1st photo AS WELL AS at least 1 week after the 2nd photo, as per Fig. 1.

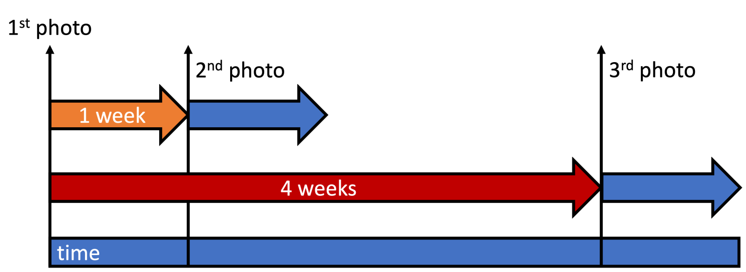


Figure 1: Diagram of time spacing for sunset(/sunrise) photos.

Submit the 2nd and 3rd photos as part of the 2nd part of the project.

12.1.5 Location documentation

All 3 photos must be taken from the same location. Bearing this in mind, we advise you to pick a location where:

1. you can get to the location again regularly later in the semester
2. a clear view of the horizon is visible

3. an area of the horizon is visible along which the sunset(/sunrise) will shift along over time.

   In the spring, the sunset shifts north over time, which is to the right, and vice versa for the sunrise. This is reversed in the autumn.

4. there are features on the horizon that allow you to pinpoint the exact position of the sunset and how it moves over time. Refer to the lecture during lab for examples of acceptable and unacceptable photos.

Additionally, it is important that you precisely document your location. You should provide enough information such that others can return to it and replicate your pictures. You will probably need to include a map along with photos that show clearly where you are standing when you take the pictures. Similar to the sunset photos, make sure features around your location are visible so your precise location can be pinpointed.

Submit the location documentation along with the 1st sunset photo for the 1st part of the project.

12.1.6 Stellarium screenshots

As we have in other labs, you'll set Stellarium to show the view from the same location and time as your photos, and then take screenshots, which you will submit. You can also click on the Sun to display information about it, including its altitude and azimuth, which we will ask you to report in the project report. These are meant to help you double-check your answers and help you get points.

Submit 1 screenshot corresponding to each of the 3 photos for the 2nd part of the project.

12.1.7 Annotated photo

The annotated photo is a **copy** of one of your photos, on which you will mark the positions of the sunsets from your other photos. Also, based on the angular scale of your camera (from calibrating it in Lab 2), predict where the sunset will shift to on 21 Dec (for fall semester)/21 Jun (for spring semester) and mark this position as well. You can make use of your calibration grid pictures for this. Fig. 2 shows a diagram of how the photo might look.

Submit the annotated photo as part of the write-up of the project report, which is part of the 2nd part of the project.

12.1.8 Project report

The project report consists of a quiz section and write-up section, both on Moodle. You will not have a submit a separate document for it.

The quiz section will have you enter specifics about your photos, including date, time, azimuth of sunset, calibrated angular field of view, and so on. The write-up section

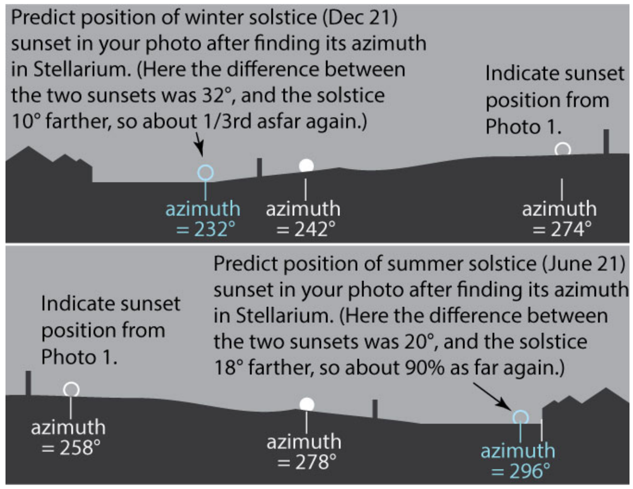


Figure 2:

will ask you to explain the procedure you used for predicting the position of the sunset(/sunrise) on the 21 Dec (for fall semester)/21 Jun (for spring semester) and locating it in the horizon view in your photo.

Note that the annotated photo is part of the submission for the write-up section. This does not, however, mean that either can be substituted for the other, i.e. an annotated photo cannot be taken to replace the write-up, or vice versa.

Happy touching grass!

13 Project: Moon in daytime

13.1 Worksheet

13.1.1 Submission overview

For the project, you will be submitting the following:

1. Zoomed-out photo of Moon in daytime
2. Zoomed-in photo of Moon, taken at same time
3. Zoomed-in photo of golf ball model Moon from scale distance
4. Stellarium screenshot
5. Project report

13.1.2 Moon photos

For this project, get a photo of the Moon during the daytime. You can do this from anywhere, and take two pictures at one time.

1. Take one photo zoomed-out as much as possible (but not past zoom $1\times$, same as for the sunset photos project), showing both the horizon and the Moon visible. (The Moon will look very small in this picture.)
2. Take a second picture zoomed-in as much as possible on the Moon, at the same time (i.e. right before or after the zoomed-out photo).

Reference Fig. 3 for an idea of what the photos might look like.
Submit both the photos as part of the project.

13.1.3 Model Moon photo

In Lab 4, you will have had a chance to take a fully zoomed-in photo of the golf ball, which we are using to model the Moon, from a to-scale distance. As your camera's zoomed-in angular field of view should be consistent (as long as the camera and zoom settings are the same), the size of the golf ball in this photo should be similar to the size of the actual Moon in your zoomed-in photo of it. If you did not have a chance to do so, let us know so you can make it up.

Submit the photo as part of the write-up portion of the project.

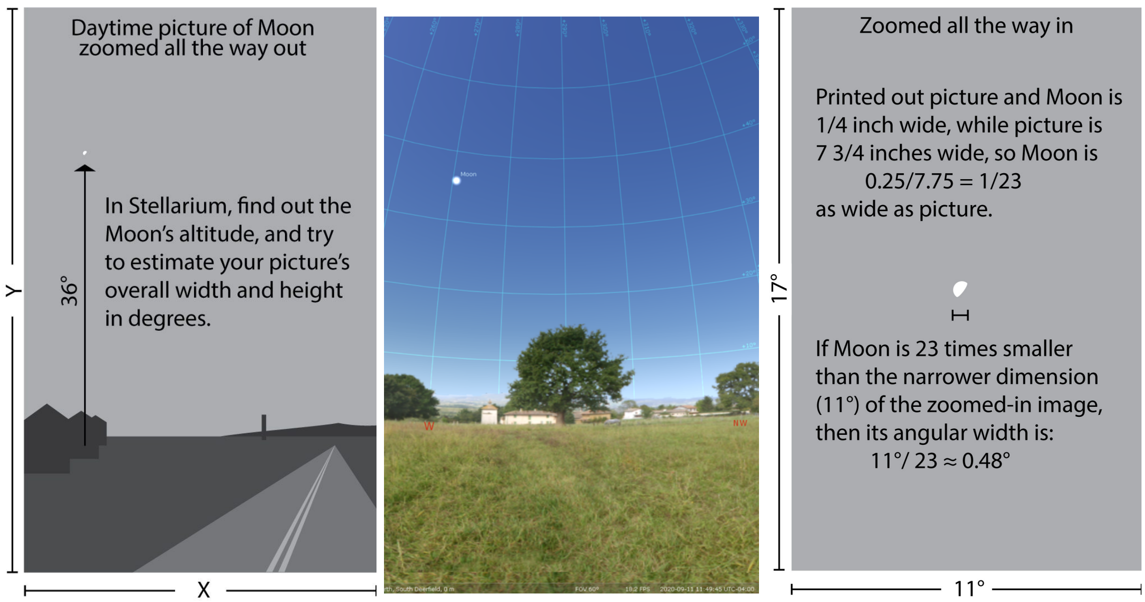


Figure 3:

13.1.4 Stellarium

Similar to the sunset photos project, take a screenshot of Stellarium set to the same location and time as the zoomed-out photo. Make sure to click on the Moon to show its information. It should look something like what's shown in Fig. 3 (which unfortunately does not show the information panel that you should include.)

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 with the phase of the Moon, and Stellarium can be very helpful in figuring this out.

You can also search on the internet for moonrise and moonset times, and then you work out where the Moon will be as it goes from east to west. You will also have to plan around the weather.

Submit the screenshot as part of the project.

13.1.5 Project report

Similar to the sunset photos project, the project report consists of a quiz section and write-up section, both on Moodle. You will not have a submit a separate document for it.

The quiz section will have you enter specifics about your photos, including date, time, azimuth and altitude of the Moon, times of sunrise and sunset, and calibrated angular field of view. The write-up section will ask you to discuss the following:

1. Compare the altitude of the Moon to the height (in degrees) of your zoomed-out calibration picture. Do these values make sense? Explain how they make sense or what might explain any discrepancy.

2. For the zoomed-in picture, how big is the Moon compared to the width (in degrees) found in your zoomed-in calibration photo? Do you get approximately 0.5° for the width of the Moon? Explain how you are making your estimate and/or any problems you had in making the measurement.

3. Place the picture of the golf ball model Moon alongside your zoomed-in photo of the Moon in a document and upload it. Comment in the essay box how similar or different the sizes are in the two photos, and discuss any difficulties.

Note that the 3rd item asks you to upload a separate document containing your photo of the golf ball model Moon and your zoomed-in photo of the actual Moon.