Phys 10293 Lab #1:
<u>The Sun and the Constellations</u>

<u>Introduction</u>

Astronomers use a coordinate system that is fixed to Earth's latitude and longitude. This way, the coordinates of a star or planet are the same everywhere on Earth. This coordinate system is called the "Celestial Sphere".

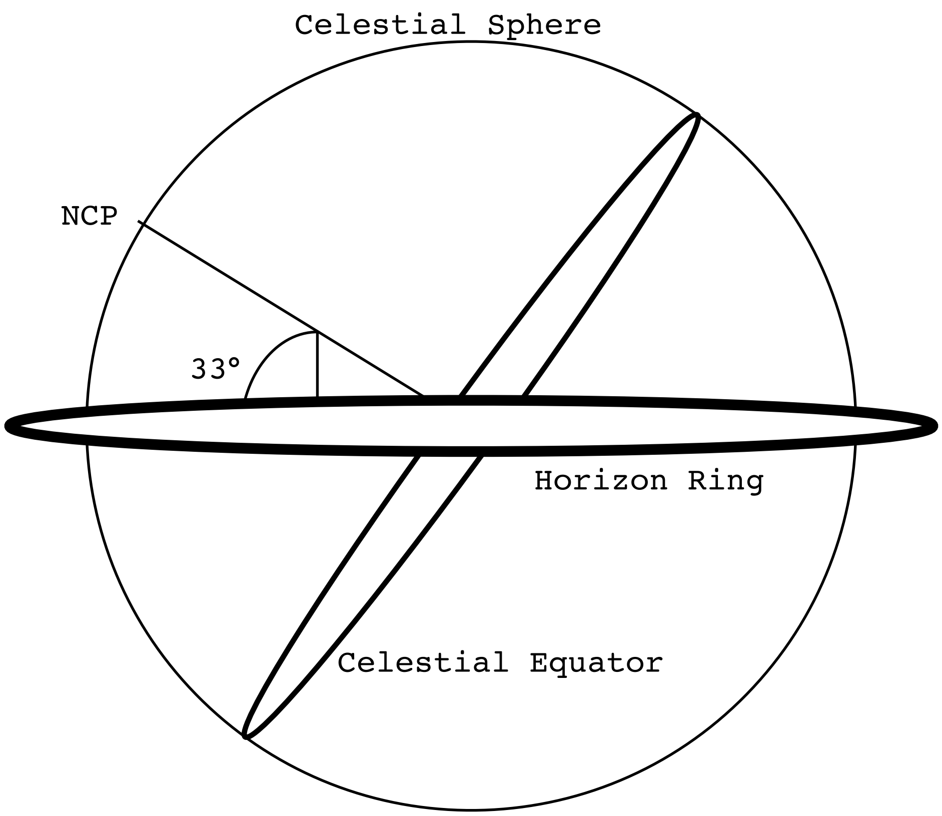
The celestial sphere can be represented by a small model (we assume the little Earth is represented at the center). On each model, you can see a grid-like coordinate system on the surface. The Celestial Sphere coordinate system assumes all the stars and planets in the sky are at an equally large distance, "painted" somewhere on the surface of the sphere.

The major circle on each model is the Celestial Equator (see if you can locate this line on your sphere). The Celestial Equator is just a projection of Earth's equator onto the night sky. You can easily see in the clear models that the Celestial Equator lies directly over Earth's equator. The grid circles that run around the globe parallel to the Celestial Equator are a measure of Celestial Latitude (also called **Declination**). The lines perpendicular to Declination lines are Celestial Longitude lines (also called **Right Ascension**).

Since the latitude of the Earth's equator is 0 degrees, we can also say that the Declination of the Celestial Equator is 0 degrees. Likewise, the North Celestial Pole (NCP) is just the projection of the North Pole onto the sky (the NCP has a Declination of 90 degrees North). The ring that surrounds the Celestial Sphere and is parallel to the tabletop is meant to represent the observer's horizon (we'll call it the **Horizon Ring**), but it will only make sense if the Celestial Sphere is set up properly. So that will be our first step...

Step 1

From lecture, you should recall that the altitude of the North Celestial Pole above the Northern horizon is equal to your latitude. We can use this information to set up the Celestial Sphere model as shown on the next page. Go ahead and set up your Celestial Sphere as shown for a latitude of +33° (our latitude in Fort Worth). The vertically oriented ring is the Meridian Ring, and since the NCP is at 90 degrees on this ring, you will want to line up your <u>northern</u> horizon with the 57 degree mark to ensure there are 33 degrees between the horizon and the NCP.



Also marked on your sphere is another circle, tilted 23.5° from the Celestial Equator. This is the Ecliptic, the apparent annual path of the Sun in the sky. Along the **Ecliptic**, you will see a series of month labels (e.g. “January, February, ...”). This is so you know where exactly the Sun is located on different days during the year. The stars do not move around on the celestial sphere, but the Sun does!

Look along the Ecliptic to find the current location of the Sun (based on today's date). In the space below, write down the Right Ascension of the Sun (to the nearest hour) and the Declination of the Sun (to the nearest degree). Use a tiny sticker on your sphere to denote the current location of the Sun or use the little yellow sphere in your model. Or you can just keep your finger on it while you proceed through the next steps.

Coordinates of the Sun today:

RA = __________ hours, Dec = ___________°

Step 2

Let's start this lab by looking at how the night sky changes over the course of a year. Today, when the Sun sets, you can tell what constellations will be up in the sky by simply looking around at the part of the celestial sphere above the horizon. We define the zenith to be the highest point above the horizon (so it would be the point on your sphere that is furthest from the table-top, or furthest from the horizon ring).

Spin your celestial sphere to a position for which the Sun is just setting below the Western horizon, then look to find out which constellations are close to the zenith point (and will therefore be high overhead tonight at sunset) as well as which bright stars are close to the zenith point. Write down the names of these objects in the space below.

Name two zodiacal constellations close to zenith at sunset tonight:

_______________, _________________

At sunset tonight, what direction along the horizon should you look to see the constellation Orion?

____

At sunset tonight, what direction along the horizon should you look to see the constellation Lyra?

____

Step 3

The galaxy Andromeda (also called the M31 nebula) is located within the constellation Andromeda. See if you can locate this on the North Celestial Hemisphere. At what time of day (sunrise, noon, sunset, midnight) does this galaxy pass close to our zenith point from Fort Worth? Answer this and other related questions below.

When does M31 (Andromeda galaxy) pass close to our zenith, as viewed from Fort Worth (sunrise, noon, sunset, midnight)?

____

When is the constellation Gemini closest to zenith (sunrise, noon, sunset, midnight)?

____

When is the bright star Arcturus (within the constellation Bootes) closes to zenith?

____

Step 4

Now let's see how the constellations change over the course of a year. On your sphere, first locate the Sun on September 21, the date of the autumnal equinox. In the space below, write down the Right Ascension (to the nearest hour) and the Declination (to the nearest degree) of the Sun on September 21.

Sep. 21 solar coordinates:

RA = ___________ hrs, Dec = ____________°

Name two constellations close to zenith at sunset on Sep. 21:

________________, _________________

When is Andromeda (M31) closest to zenith (sunrise, noon, sunset, midnight)?

____

When is Gemini closest to zenith (sunrise, noon, sunset, midnight)?

____

Step 5

You may notice as the Sun moves along the ecliptic during the year, it moves through a series of 13 constellations. These constellations therefore have special significance to some people. Your astrological sign is supposed to be the constellation the Sun is in on the day of your birth (time of day doesn't matter ... as you can see, the sun doesn't move much during one day relative to the background stars and constellations).

Find out what sign the Sun is in on your birthday. The position of the ecliptic relative to the constellations does wobble over thousands of years, which can cause the dates associated with certain constellations to change. We will explore this phenomenon in a later lab.

What is the month and day of your birthday? ___________________

In what constellation is the Sun on this day? __________________

Step 6

Now let's focus on the daily motion of the Sun on a few different days during the year. First, return your Sun marker to today's date and let's analyze the Sun's motion through the sky. We want to find out the Sun's setting azimuth as well as its noontime altitude above the horizon.

The Sun's azimuth at sunset can be found by measuring along the horizon ring. With the Sun located on the ecliptic on today's date, rotate your sphere so that the Sun is on the Western horizon.

When the entire Sun dips completely below the horizon ring, that is the time of sunset. Due West on your ring is at an azimuth of 90 degrees, but your setting sun is likely somewhat north or south of this point, depending on the time of year. If your setting Sun is south of West, then you might see a degree measure along the horizon of, say, 110 degrees. That is equivalent to 20 degrees South of West. By contrast, if the Sun is at an azimuth of 75 degrees, that would be the same as saying 15 degrees North of West.

You can find the Sun's noontime altitude above the horizon in the same way you set up the North Celestial Pole. Look at what degree mark is on the Southern horizon and count off degrees along the vertical Meridian Ring until you reach the Sun's location. For example, if the meridian ring says 55 degrees on the Southern horizon and 23 degrees where the Sun crosses it today, then the Sun's altitude is (55 - 23 =) 32 degrees.

Now let's estimate the day length. You can do this by starting with the Sun on the Eastern horizon. Now, keep your eye on the Western horizon and slowly turn the sphere so that the sky passes down through the Western horizon (objects set in the West). As each hour on the Celestial Equator passes below the horizon, one hour of time passes. Count off the hours until you see the Sun drop below the Western horizon...that's how long the Sun is above the horizon during the day: the day length.

Finally, repeat these measurements for a different latitude on Earth: Fairbanks, Alaska, which has a latitude of 60° North.

Today as seen from Fort Worth....

the Sun rises __________ degrees South of East.

the Sun sets ___________ degrees South of West.

the Sun's altitude above the Southern horizon at noon is

____________ degrees.

the length of the day (to the nearest hour) is about

_____________ hours.

Today as seen from Alaska (latitude 60° North)...

the Sun rises __________ degrees South of East.

the Sun sets ___________ degrees South of West.

the Sun's altitude above the Southern horizon at noon is

____________ degrees.

the length of the day (to the nearest hour) is about

_____________ hours.

Essay

In your essay, use the results of your lab to explain why the constellations overhead at midnight change over the course of a year. A simple diagram may help. In the next paragraph, explain why winters in Alaska are colder than winters in Fort Worth (if you are doing this lab in January). Use the results from step 6 to support your answer.

(space for diagram)

Physics 10293 Lab #2:
Starry Night Introduction

Introduction

In this lab, we'll learn how to use the Starry Night software to learn about the sky. Starry Night has a large number of features and options, and we will explore some of the most useful ones for our purposes.

Step 1

First, start up the program. You should find a shortcut for Starry Night College on your desktop. When the program first starts up, you may be asked to update data or the software. Just hit "later" for these and ignore them. TCU Technology Resources is responsible for keeping the software updated, so we don't need to worry about it. You will need to tell it where you are viewing from. You can select Fort Worth from the list or (faster) search for it.

Once you have selected your location, the left sidebar will likely be open to the SkyGuide. If it is not, search the tabs on the left-hand side of the screen and select SkyGuide. We are going to use the bottom link in this lab, entitled "Starry Night basics". So click on that link.

Step 2

We are going to go through some (but not all) of the steps to learn the basics of Starry Night. Start with the first link, entitled "Starry Night for the First Time." You can use the scroll bar to scroll down and read this entire window. When you are finished, click on the bottom link, which will take you through the remaining introductory pages in order. As you go through these pages, you will find that you have the tools to answer the more complex questions I will ask on your worksheet.

Answer the questions on your worksheet using Starry Night to help find the information you need. As always, raise your hand and ask for help if you have questions. You may work with a partner for this lab, but each of you should spend an equal amount of time "driving" the software.

Lab #2 Worksheet

Name:
Home TA:

After you have read "Changing your viewing direction" and "Changing the date and time", answer the following questions:

Look toward the Western horizon and set today's time to 430pm.

In what constellation is the Sun located? ________________________

At what time does the Sun set tonight? __________________________

--
After you have read through "Identifying objects in the sky", answer the following:

Look toward the Northwestern horizon and set the time to 11pm, then turn on labels using the L key on your keyboard.

What type of object is M82? ___________________________

What type of object is M37? ___________________________

How far is the bright star Castor from Earth? __________________

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After you have read through "Displaying constellation figures" and "Finding an object", answer the following:

Set the time to 4am today. Use the "Find" tab on the sidebar to find the planet Saturn, then center on it.

In what constellation is Saturn found? _________________________

Set the time to 7pm today, then use the "Find" tab to find and center the planet Jupiter.

In what constellation is Jupiter found? ________________________

If you have used the “Find” sidebar to find and automatically center on Jupiter, then the altitude and azimuth of Jupiter should appear on the top information bar near the right hand side of your screen.

What is the altitude of Jupiter above the horizon? ____________

Read through “zooming in on an object” in the SkyGuide sidebar, then zoom in on Jupiter and answer the following.

Which of Jupiter’s moons casts a shadow on Jupiter at this time (7pm)? If none do, you can just say that.

____

Use the search option in the Find sidebar to find the Pleiades open cluster.

In what constellation is the Pleiades found? __________________

Name three of the seven sisters that make up the Pleiades (Atlas and Pleione are the “parents”, they don’t count).

___________________, ___________________, ___________________

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Now we’re done with the sky guide, but we will still explore a few more features of Starry Night.

Set the time and date to 8pm Feb 14, 2011, then scroll around the sky to locate and center on the Moon (in what general direction should the full moon be just after sunset?) Open the info tab in the sidebar, and use it to answer the following:

In what constellation is the Moon? _____________________

What is the Moon’s phase? _____________________________

--
Use the “Now” button just beneath the clock on the top left information bar to return to today’s date and time. Use the find sidebar to find and center on the Sun, then open up the info tab.

What is the declination of the Sun, to the nearest degree? _____

Click on the “sunset” button below today’s date and time in the top information bar, then just beneath the time flow rate indicator, click the “stop” button. You should now be looking at the Western horizon with the Sun hidden behind the scenery.

For simplicity, let’s remove the trees and scenery. Under the options menu, select Other Options --> Local Horizon. On this screen, select “Flat” for Horizon style. You should now be able to see the Sun as it is setting below the horizon.

What is the Sun’s azimuth, in degrees? ________________

If West is 270°, how many degrees South of West is this? ________

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Now set the date to the vernal equinox, March 20 and the time to sunset.

What is the Sun’s azimuth, in degrees? _____________

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Now set the date to the summer solstice, June 21 and the time to sunset.

What is the Sun’s azimuth, in degrees? _____________

How many degrees North of West is this? ____________

Such precise measurements are key to understanding the alignments of ancient skywatching sites such as Stonehenge. Return to today’s date and time and look due North. Now in order to see circumpolar motion, we will increase the rate time flows. On the top information bar, change the time flow rate to 3000x.

Name a bright star in Ursa Major that is circumpolar, which means it always remains above the horizon.

____

Now use the top information bar under “Viewing Location” to switch your location to Singapore (under “Other...”). You should stop the time flow so we can set the time.

What is the altitude of Polaris above the Northern horizon at 930am on today’s date? Remember, you can get this information in the info tab.

____

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Now we will track the Sun’s motion. Use the “home” button below “Viewing Location” to return to Fort Worth. This also returns us to today’s date and time. For reference now, we will turn on the meridian on the screen. Under the “View” menu, look for the sub-menu “Alt/Az guides” and select “Meridian” there. Now adjust today’s time until (looking South) you see the Sun cross the meridian.

When then Sun crosses the meridian, it is at its highest point in the sky. When the Sun is on the meridian today, what is its altitude above the Southern horizon?

____

Based on the rise and set times, what is the day length to the nearest hour?

____

On March 21, what is the Sun’s altitude when it is crossing the meridian?

____

On June 21, what is the Sun’s altitude when it is crossing the meridian?

____

Based on the rise and set times, what is the day length to the nearest hour on June 21?

____

Let's compare the Sun's motion in Fort Worth with the Sun's motion as seen from Alaska. Set your location to Fairbanks, Alaska. The date should still be June 21.

What is the Sun's altitude when crossing the meridian? ________

Based on rise and set times, what is the day length? ________ hrs

Now set the date to December 21 from Fairbanks. You may need to use the Options --> Other Options --> Local Horizon menu to again block out the scenery so that you can see the Sun.

What is the Sun's altitude when crossing the meridian? ________

Based on rise and set times, what is the day length? _______ hrs

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Finally, let us consider the zodiacal signs. If you read your horoscore in the newspaper, you may find the following "official" dates apply:

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

For your essay, address the following questions:

In the first paragraph, state your birth day and then use Starry Night to determine your "correct" astrological sign for the date of your birth. State whether this is different from the sign found using the common, mistaken dates above.

In the second paragraph, explain whether your opinion about the validity of horoscopes has changed. Assuming you have the opportunity in the future to check your horoscope, explain whether you will check your "correct" sign or your sign based on the dates given above? Which would you give preference to and why? If you don't believe horoscopes are valid in the first place, explain why you think this.

Physics 10293 Lab #3:
Starry Night –
Observations of the Sun and Moon

Introduction

Today, we are going to use the Starry Night software to learn about motion of the stars, sun and moon on the celestial sphere. At each step along the way, I will ask you a few simple questions to check your understanding of what you are seeing.

First, start up the program and make sure your location is set to Fort Worth for today's date and time. Turn your view toward the West, then we will make a few changes to what you are seeing so that it more closely resembles one of the celestial sphere models we worked with during the first week.

Step 1

Click the "Options" sidebar (not the top options menu). The tab for the options sidebar is on the left side of the Starry Night viewscreen just beneath the top choice "Find". Once that is open, do the following...

- Make sure the Guides window is open on top of this sidebar
- Click on the + sign to expand Alt-Az guides
  Check the Local Equator (Horizon) option

- Click on the + sign to expand Celestial guides
  Check the Equator option
  Check the Grid option
  Check the Poles option

- Click on the + sign to expand Ecliptic guides
  Check the Ecliptic option

- Click the + sign to expand the Local View window
  Uncheck the Daylight option
  Uncheck the Local Horizon (lake) option

- Click the + sign to expand the Solar System window
  Uncheck the Asteroids option
  Uncheck the Comets option
  Uncheck the Satellites option
  Uncheck the Space Missions option

- Click the + sign to expand the Constellations window
  Check the Boundaries option
  Check the Labels option

Your screen should now resemble what you would see if you could stand on the tiny Earth inside one of the transparent celestial sphere models. Zoom out and back in to see the whole sphere. Now scroll around the screen and find some information about various objects you see in order to answer the questions below.

In what constellation is the Sun today? ________________________

What time does the Sun set today? __________________

How long is the day today, to the nearest hour? _____________ hrs

What constellation will the Sun move to next as it travels along the ecliptic? _________________________

Find the North Celestial Pole (NCP) on the sky. What constellation is the NCP in? ______________________

What is the name of the bright star found very near the NCP on the sky? ______________________

Find the South Celestial Pole (SCP) on the sky? What constellation is the SCP in? ______________________

Since there is no star close to the SCP, navigators long ago used the constellation Crux, also known as the Southern Cross, to help find the location of the SCP and thus the direction true South.

Find the constellation Crux and within it, the star Acrux. How far is Acrux from Earth? ______________ ly

The “ly” units stand for “light years”. The nearest star to us, besides the Sun, is Alpha Centauri, about 4 light years away.

Step 2

Next, we will study the motion of the Moon. First, <u>use the find sidebar to find the moon</u>. Just enter “Moon” in the search box, and the program should find and center the Moon for you. Within the Find window, the Moon has two checkboxes to the left of its name (both checked) and two checkboxes to the right (both unchecked). If you hover the mouse over each checkbox, it will tell you what the checkbox is for. <u>Check the box to label the Moon’s orbit</u>.

You should now see the Sun’s apparent annual orbital path in the sky (the Ecliptic) and the Moon’s apparent monthly orbital path in the sky both as green lines. We know that we can only get lunar or solar eclipses during “eclipse seasons” when the Moon’s orbital path and the Sun’s orbital path cross every six months.

It will help if we now find and center on the Sun so that we can keep the Sun in the center of our screen as we move time forward. <u>Use the find sidebar to find the Sun</u>. Type “sun” into the search box and then below that, double-click on the Sun from the list of possible objects. The program should now smoothly scroll around the sky until your view is centered on the Sun.

Take note of which constellations you can find the intersection of the Moon and Sun orbits. The intersection points are called “nodes”. You may need to zoom in to see the intersection clearly in some cases. Answer the associated questions below.

In which two constellations do the orbital paths of the Sun and Moon intersect this year?

_________________, ___________________

What days of the year (this year) does the Sun cross the Moon’s orbital path? You may need to run time forward/backwards to see this. These are the dates around which lunar and solar eclipses are possible.

Earlier crossing on __________________________

Later crossing on _________________________

Minimize Starry Night for the time being and open up a browser window. Visit the web site http://eclipse.gsfc.nasa.gov and find out the dates closest to the two dates above (should be within a month) on which we see solar eclipses somewhere on Earth.

______________________ and _______________________

Access Starry Night again and set time forward to January, three years from this year. During the new year you have set, find the crossing dates:

Earlier crossing on _________________________

Late crossing on _________________________

Again, using NASA's eclipse web page, find the two dates closest to the above dates on which we will see solar eclipses. You can find this using the Decade Solar Eclipse Tables under the large heading Eclipses of the Sun.

_______________________ and _______________________

Step 3

The motion of this intersection (the node) through the sky is due to the fact that the Moon's orbit wobbles. Each year, the Moon's orbital plane, which is tilted 5° with respect to the Ecliptic, wobbles. This causes the nodes to shift positions on the sky by about 20 degrees in Celestial Longitude (Right Ascension). So each year, the eclipse time table moves by about 20 days forward. In Step 2, your dates for eclipses three years from now should be about 60 days later than the dates for this year.

It takes approximately 18 years for the nodes to return to their original location. This time period is called a Saros Cycle. Ancient astronomers recognized this motion of the Moon and Sun and could thus predict eclipses with some accuracy by measuring the precise location of the Full Moon as it would set along the horizon.

Let's do an example together. Use the find and info functions of Starry Night to gather data on the positions of the Sun and Moon on certain days of the year. To begin, find the first full moon of this calendar year. Now look to the Western horizon and set the time to sunrise on that day (there is a button just below the time display to do this). You should see the full moon near the horizon. Adjust the time minute-by-minute until the full moon sets (when the top bit of the moon is just dipping below the horizon).

There are a couple of different ways to get the information about the azimuth of an object. One is to use the find tab to find and center on the object. Once the screen is centered on the object you are trying to find, the object's azimuth (and altitude) will appear on the "Gaze" window on the upper right of your screen. The other way is to right-click on the object and go to the bottom of that menu to "Show Info". Then the azimuth will appear on the left in the info sidebar.

Now start filling in your data table on the last page of the lab. Note the date and the azimuth of the full moon (info tab on the sidebar) at moonset (which is near sunrise but not exactly at sunrise most of the time). Now switch the time to sunset. Your screen should now show the Sun dipping below the Western horizon. Click on the Sun (it may take some zooming and/or precise clicking to do this) to get the Sun's positional information to appear in the info sidebar. Record the Sun's azimuth at this time.

Now repeat for each of the 12 or 13 full moons that will occur during this calendar year. Each full moon date should be separated by about 29-30 days. Note that the moon is technically full sometimes on two different days, and it doesn't matter which of those two you choose for our purposes.

<u>Step 4</u>

There is a good possibility of eclipse when the Sun, Earth and Moon are precisely lined up, so how can you tell when they are lined up? You may notice from your observations that when the Full Moon sets North of West, the sun tends to set South of West and vice versa.

Suppose the full moon sets 20 degrees South of West. We are likely to get an eclipse of the sun sets equally far (20 degrees) North of West. So on this table, I've included some columns for you to do simple calculations. For each line of recorded data, fill in the relative azimuths of the Sun and Moon, where West is 270 degrees.

For example, if the Moon sets at an azimuth of 293 degrees, that is (293-270 =) +23 or 23 degrees North of West.

On the same day, if the Sun sets at an azimuth of 242 degrees, that is (242-270 =) -28 or 28 degrees South of West.

Since these numbers aren't the same, there is no chance of an eclipse.

On a different day, if you get -11 for the Full Moon set and +11 for the sunset, then an eclipse is likely. Even if the numbers are only different by 1 (or 2 at the most), an eclipse is likely since there is some margin for error.

Step 5

Based on your table, during which months of this year are we likely to get eclipses? Write down this answer below and then go online to http://eclipse.gsfc.nasa.gov and find out during which months of the year lunar or solar eclipses are actually occurring.

Based on your table in step 4, during which months are eclipses likely?

____

Compare your answer to the published eclipse dates listed above in step 2 for this year. They should be pretty close (within a month or two for sure).

Date	Azimuth of Full Moon Set (near sunrise)	Azimuth of Sun Set	Moon Azimuth - 270	Sun Azimuth - 270

Physics 10293 Lab #4:
Starry Night – Student Exercises I

Introduction

For today's lab, we are going to let the Starry Night software do much of the work for us. We're going to walk through some of the sample setups provided by Starry Night to understand some of the concepts we've talked about in lab and lecture this semseter.

Part A1

First, we will look at the relationship between the solar day and the sidereal day on Earth.

Open the SkyGuide tab on the sidebar...

- Select Student Exercises
- Select A - Earth, Moon and Sun
- Select **Exercise A1:** Diurnal Motion
- Select Part 2: Diurnal Motion Rate, and answer:

At what rate (degrees/hour) does the Sun move? ____________

Now select Part 3: The cause of diurnal motion, and watch the associated animation.

Now select Part 4: Diurnal motion and location, and answer:

Describe the difference in the daily path of the rising Sun as seen from New York (latitude 41° N) and Quito, Ecuador (latitude 0°).

Part A2

Now move on to **Exercise A2:** Earth's revolution around the Sun. For Part 1: Night sky changes daily, follow the instructions carefully (step time forward only once, do not run time forward) to determine how long it takes for the star Vega to return to the meridian each day as measured from its previous day's meridian crossing. Note the start time below before you begin the exercise.

How long does it take the star Vega to return to the merdian to the nearest second?

Start: Aug 14, 2010 8 hr 59 min 32 sec

Return to meridian, Aug 15, 2010 _____ hr _____ min _____ sec

Length of sidereal (stellar) day to the nearest minute: ______ hr ______ min

Now click on Part 2: Constellations shift throughout the year, and answer:

On what date in the exercise is the constellation Leo on the meridian at midnight?

____

Now move on to Part 3: The cause of shifting constellations. This simulation is showing you a view of the Earth as seen from the Sun. The constellations back behind the Earth are the ones seen by the night-time side of Earth. These are the same constellations we watched pass through the meridian in the previous step.

Part A3

Now move on to **Exercise A3:** The Local Coordinate System. The first view shows a view of the sky like that seen in the back of your textbook, only with the local altitude and azimuth coordinate system overlaid. You can see as you look around the horizon that the azimuth angle varies from 0° (true North) to 90° (East) to 180° (South) to 270° (West) and then back to 0°. Also, note that East and West on the sky map is reversed from a normal map just like in your book's star charts.

Work through <u>Part 1: Altitude and azimuth</u> and answer:

At the beginning of the exercise, what is the approximate altitude of the star Regulus? _______________

After two hours passes, what is the altitude? ____________

At the same time, what is the altitude of the constellation Gemini? _____________

At the same time, what is the approximate azimuth direction (e.g. N, NE, E, SE, S, etc.) for the constellation Orion? _____________

At the same time, what is the approximate azimuth direction of the constellation Ursa Major? ____________

Now start <u>Part 2: The meridian</u> and answer the associated questions below . Note that you can determine the altitude of Antares by right-clicking and going to the bottom of the menu to "show info" (look under "Position in the Sky" in the sidebar). But then be sure to return to the skyguide tab when you are done.

At what time does Antares cross the meridian? ______________

What is the altitude of Antares at this time? _____________

From <u>Part 3: Altitude and latitude</u>:

What is the altitude of Antares from 53° N latitude? ___________

At the same time, what is the altitude from 25° N? ____________

Part A5

Skip ahead to **Exercise A5: The Celestial Sphere**, and work through the 8 associated exercises, answering the associated questions below:

From Part 1: The celestial equator:
For each of the following constellations, answer "yes" if it is on the Celestial Equator and "no" if it is not on the Celestial Equator.

Orion _______________ Gemini ________________

Cetus _______________ Ursa Major ______________

Scorpius _______________ Virgo _____________

From Part 4: North celestial pole and an observer's latitude:
If you want to use the angular separation tool, you can access that at the top left where the hand with the + sign is located. There is a little drop-down menu to the right of that that allows you to select different tools. The angular separation tool works by clicking on a particular place on the sky, then dragging to the other place. You can also estimate the altitude of the North Celestial Pole above the horizon by clicking "Show Info" on Polaris.

What is the altitude of the NCP from New York City? __________

What is the altitude of the NCP from Key West? ___________

From Part 7: The equinoxes and Part 8: The solstices, determine the dates when the Sun approaches each reference point on the sky. You may wish to increase the rate of time flow for these parts.

What day does the Sun reach the Vernal equinox? _______________

What day does the Sun reach the Autumnal equinox? _____________

What day does the Sun reach the Summer solstice? ______________

What day does the Sun reach the Winter solstice? ______________

Part A6

Work through **Exercise A6:** The Celestial Coordinate System and work through the 6 associated exercises, answering the corresponding questions below.

From Part 3: Right Ascension:
What is the Right Ascension of each of the following points?

The Vernal equinox: _____________ hours

The Summer solstice: _____________ hours

The Autumnal equinox: _____________ hours

The Winter solstice: _____________ hours

From Part 4: Measuring Coordinates:
What are the coordinates of Altair?

RA = _______________________, Dec = _____________________

Which star is at the coordinates RA = 3h 59m, Dec = -13° 28′?

____

Which star is at the coordinates RA = 13h 48m, Dec = +49° 14′?

____

From Part 5: Celestial coordinates and an observer's location:

What are the coordinates of Vega as measured from New York City?

RA = ____________________, Dec = ___________________

What are the coordinates of Vega as measured from Quito, Ecuador?

RA = ____________________, Dec = ___________________

Notice that the altitude and azimuth of Vega varies depending on one's location (these are local coordinates) while RA and Dec of Vega is independent of location (global coordinates). Each type of coordinate is useful in certain situations. RA and Dec are typically used in star maps used around the world.

From Part 6: Precession:

What are the coordinates of Vega in the year 3009?

RA = ____________________, Dec = ____________________

When studying the alignments of temples and monuments in ancient cultures, we must be sure to adjust for precession before determining whether or not there is an alignment with the particular star or constellation.

Part A7

Work through **Exercise A7:** Solar and Sidereal Days and the four associated exercises, answering the corresponding questions below.

From Part 1: Apparent Solar Day, to the nearest second, what is the length of the solar day on

June 21-22, 2010: ________ hours _______ min _______ sec

September 21-22, 2010: _______ hours _______ min _______ sec

Briefly summarize what causes the variation in the solar day.

From Part 4: Sidereal day, to the nearest second, what is the length of a sidereal day?

________ hrs ________ min ________ sec

Note that this length does not vary with time of year as it depends only upon the Earth's rotation speed, which is constant. The solar day depends on both the Earth's rotation speed and Earth's orbital speed, the latter of which is not constant.

In Part 3: Equation of time, you are introduced to the analemma, which is constructed by marking the Sun's location in the sky on successive 24-hour intervals. The Sun moves north and south along the meridian due to the tilt of the Earth as it orbits the Sun. This North-South motion gives us the seasons. If you go to the Options sidebar and display Equator under Celestial Guides, you can see the Sun moving north and south of the Celestial Equator as we have shown on horizon diagrams.

The east-west motion to either side of the meridian comes from the varying speed of Earth as it orbits the Sun, as explained in part 1 of this exercise. The up-down motion combined with side-to-side motion creates the analemma.

Part A8

Work through **Exercise A8: The Year and Seasons** and the five associated exercises, answering the questions below.

From Part 1: Earth's orbit, answer the following. Remember, you can find the distances or angular distances between two things by using the angular separation tool, which is accessible on the menu in the top left corner just to the left of the time and date control panel.

1 AU (Astronomical Unit) is the average distance from the Earth to the Sun, equal to 93 million miles. We measure distances in our solar system in AU for convenience.

What is the Earth-Sun distance on Dec 21? ______________ AU

What is the Earth-Sun distance on Jun 21? ______________ AU

What is the percentage difference? You can calculate this by taking the difference and multiplying by 100. ________%

From Part 5: Seasons on Mars, answer: Does Mars experience seasons like the Earth? Explain.

Part A9

Work through **Exercise A9:** The Analemma and the five associated exercises, and answer: Is Mars' orbit more eccentric than Earth's? Less? About the same? Explain your answer, based on the shape of its analemma.

Essay

Look back through each part of this lab and pick the one that (a) was most interesting to you and then pick the part that was (b) most helpful in your understanding of a concept you didn't previously understand. Briefly justify each choice with a sentence or two of explanation.

Physics 10293 Lab #5:
<u>Starry Night – Student Exercises II</u>

<u>Introduction</u>

We will continue today exploring some of the useful applications of the Starry Night software to learn about motions in the sky.

<u>Step A10</u>

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises".

Select "A: Earth, Moon and Sun". This will open a list of exercises, and we will work through the last four.

Open **<u>Exercise A10:</u>** <u>The Moon</u> and work your way through the three exercises contained in this section, answering the corresponding questions below.

Within this exercise, select <u>Part 1: The Moon's Rotation</u>. This exercise will ask you to determine the length of a sidereal day on the Moon, and we will also determine the length of a solar day. Just as a sidereal day is the amount of time it takes for a star to return to the meridian, the solar day is the amount of time it takes for the sun to return to the meridian once it leaves the meridian. The answers below will each be among the four choices offered in the exercise.

The length of the sidereal day on the Moon is __________ days

The length of the solar day on the Moon is ____________ days

The sidereal day on the Moon is the true measure of the Moon's rotation period, relative to a distant, non-moving reference frame (the stars). The solar day is the time it takes for the Moon to complete a cycle of phases as seen from Earth.

Now proceed to <u>Part 2: The Moon's revolution</u>.

How long does it take the Moon to complete one orbit around the Earth? __________ days

From Part 3: The Moon's libration: You can measure the distance from the observer to the Moon by simply hovering the cursor over the Moon. This information will be displayed on the screen to the left along with other data.

When the Moon has its smallest angular size, what is its distance from the Earth, to the nearest thousand kilometers? ____________________

When the Moon has its largest angular size, what is its distance from the Earth, to the nearest thousand kilometers? ____________________

The percentage difference in the Moon's orbital distance from Earth can be found with 100 * (biggest - smallest) / smallest ___________%

Step A11

Open **Exercise A11:** Phases of the Moon, and work your way through the ten exercises, answering below:

From Part 1: Synodic Month:

What is the length of the synodic month? ______________ days

From Part 2: New Moon:

What time of day does the new moon rise? ___________________

From Part 8: Last Quarter:

What time of day does the 3rd qtr moon rise? _______________

From Part 10: Phases are caused by the Moon's orbital motion:

At the beginning of the simulation, on Nov 16, 2005, what is the phase of the Moon? ________________

What is the phase on Nov 23, 2005? ________________

What is the phase on Nov 30, 2005? ________________

What is the phase on Dec 7, 2005? ________________

Step A12

Open **Exercise A12:** Lunar and Solar Eclipses and work your way through the eight exercises, answering below:

From Part 1: Line of nodes:

Which is the correct answer for Question 1, why is an eclipse not possible at this time?

____

From Part 2: Eclipses and the phase of the Moon:

What is the phase during solar eclipse? _________________

What is the phase during lunar eclipse? _________________

From Part 3: Lunar Eclipses

How long (in minutes) does the total lunar eclipse last (the time during which the Moon is completely inside the umbra)? _____________

According to the animation showing the a view from the Sun, looking past Earth as the Moon passes through Earth's shadow, which continent is unable to witness the lunar eclipse? ______________

From Part 4: Partial lunar eclipses

Briefly explain the difference between a total and partial lunar eclipse.

From <u>Part 5: Solar eclipses</u>

What is the date of the eclipse? ________________________

After viewing the eclipse from Shanghai, China, was the solar eclipse annular or total? __________________

Now watch the shadow of the Moon cross the Earth from a distance (the last “click here”). What body of water is the moon’s shadow over when the eclipse ends and the moon’s shadow no longer touches the Earth?

____

From <u>Part 7: Solar eclipse seen from the Sun</u>

The inner circle is the umbra of the moon’s shadow. Anyone in the path of this dark spot will see a total eclipse. The outer circle is the penumbra, within which observers will only see a partial solar eclipse.

Does Rome see a total eclipse? ___________________

The Saros cycle is an approximate 18 year period between similar alignments of the Sun, Earth and Moon. The exact length of the cycle is 6585.3 days. The next eclipse of this particular Saros cycle will begin on April 8, 2024 at 17:00 UT. UT stands for Universal Time, which is usually the same as the time on the Prime Meridian in Grenwich, England.

Set the date and time accordingly. To the nearest hour, what time will this total eclipse begin at TCU?

________________ UT

Our local time is UT - 5 hours when we are on Daylight Savings Time, so the time of eclipse start will be 5 hours earlier, roughly, from the time you estimated here.

From Part 8: Annular Eclipse

What is the distance from the observer to the Moon during this eclipse? ________________ km

Based on your answers in the first section of this lab (Part A10, section 3), is the moon near its furthest distance from the Earth (apogee) or its closest distance to the Earth (perigee)? ____________________

Step A13

Open **Exercise A13: Precession and Nutation** and work your way through the five exercises, answering below:

From Part 1: Precession of the Earth's spin axis

What is the precession period of Earth's spin axis (you may wish to increase the time flow rate for this)? _________________ yrs

What is the angular size of the precession circle? _______°

How does the size of the precession circle compare to the Earth's tilt?

____

From Part 2: Shifting Celestial Pole

In approximately what year will Vega be the "North Star"? __________________

In approximately what year in the most recent past was Thuban the "North Star"? __________________

From Part 3: Precession of the Equinoxes

In what constellation was the Vernal Equinox found during the year 200 BC? ____________________

In approximately what year will the Vernal equinox cross into the constellation Aquarius? ____________________

From <u>Part 4: Nutation</u> and <u>Part 5: Nutation Period:</u>

If you zoom in, you can see the sinusoidal wobbling motion of the stars as they move past the North Celestial Pole. Watch these wobbles for a bit and then use the buttons to start and stop time so that you can estimate how many years it takes for the axis to make one of these small nutation wobbles.

Nutation wobble period: ______________________ years

You can also do this exercise in part 5 if you are having trouble (note the dots are separated by 2 years, not 1 year as the exercise states).

<u>Essay</u>
Look back through each part of this lab and pick the one that (a) was most interesting to you and then pick the part that was (b) most helpful in your understanding of a concept you didn't previously understand. Briefly justify each choice with a sentence or two of explanation.

Physics 10293 Lab #6:
<u>Mercury</u>

<u>Introduction</u>

Today we will explore the motions in the sky of the innermost planet in our solar system: Mercury. Both Mercury and Venus were easily visible to the naked eye near sunrise and sunset, and their distinctive patterns of motion were studied closely by many cultures.

<u>Step 1</u>

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises".

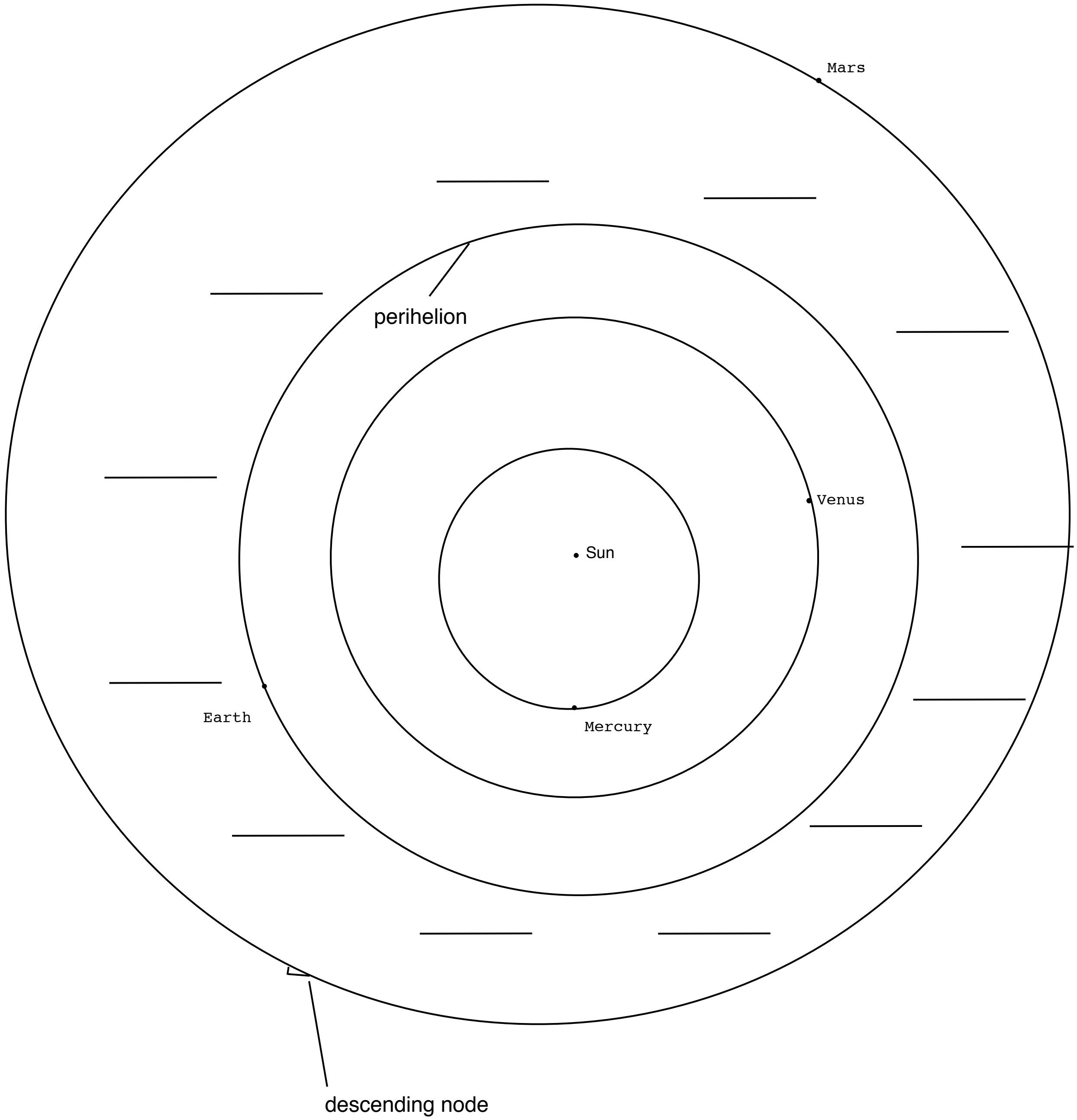
Select "C: The Planets". This will open a list of exercises.

Open **<u>Exercise C1:</u>** <u>The Inner Planets of the Solar System</u> and from here, <u>Part 1: Orbits of inner planets.</u> You may want to zoom in a little bit here so that the features are clearer.

<u>Time</u>

On your diagram on the following page, the figure on your screen has been reproduced as a negative and a few features labeled. Notice on the diagram twelve blanks surrounding Earth's orbit. By watching the motion of the planets on your screen, <u>write in three letter abbreviations in each blank corresponding to the month when Earth is in that position in its orbit around the Sun</u>.

Label the months in the diagram below.



Conjunctions

Next, notice the locations of Mercury and Venus in the diagram above. The location of Venus is on the far side of the Sun, almost exactly opposite of the Earth. We call this position "superior conjunction". Conjunction means "joining", so this is a time when the Sun and Venus are apparently joined on the sky. When a planet is between the Earth and Sun, we call this position "inferior conjunction." During conjunctions, a planet is not easily visible since it is so close to the Sun in our sky.

Perihelion

On your screen, a small tick mark perpendicular to a planet's orbital path denotes the perihelion for each planetary orbit (shown for Earth on the diagram on the previous page). Since all planetary orbits are elliptical, there will be a point in the orbit at which the planet is closest to the Sun (perihelion) and furthest from the Sun (aphelion).

Nodes

Next, notice on your screen the small half-arrows attached to each orbital path. Like the Earth's moon, the orbital planes of the planets do not exactly match up with the Earth's average orbital plane, also known as the plane of the Ecliptic.

There are two places where the planets cross through the Ecliptic plane: the ascending node and the descending node. The descending node is marked with a hollow half-arrow for each planet (this has been reproduced on the diagram on the previous page for Earth's orbit). This is where the planet is plunging down through the plane of the Ecliptic. On the opposite side of the planet's orbit (on the screen but not shown on paper) is the solid half-arrow which marks the ascending node.

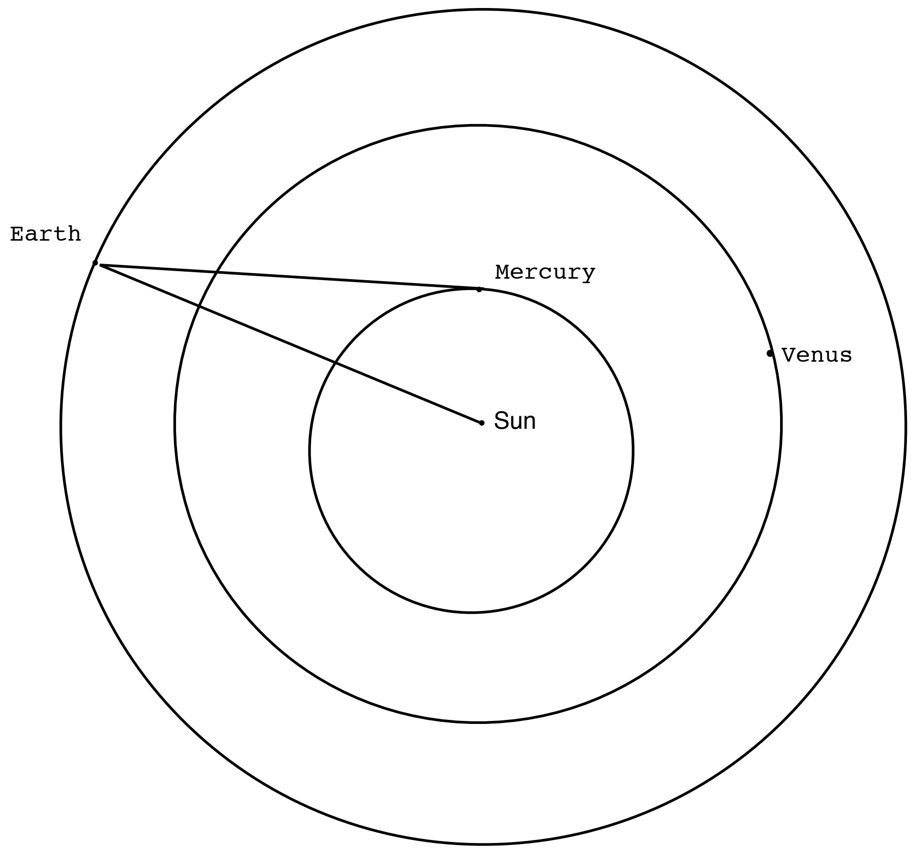
When an inner planet moves in front of the Sun like our Moon occasionally does, we do not call it an eclipse. Instead, we call it a transit. Planetary transits can occur when the planet is at a node at the same time it is lined up with the Earth and the Sun. Below, for the planet Mercury, write down which months of the year it is possible to see a transit of this planet from the Earth. This answer doesn't depend on the year.

Mercury transit is possible in which two months?

______________ and ________________.

Step 2

Below, Figure 1 shows Mercury at its perihelion point. A line has been drawn from Earth's orbit to Mercury's perihelion point.



Elongations

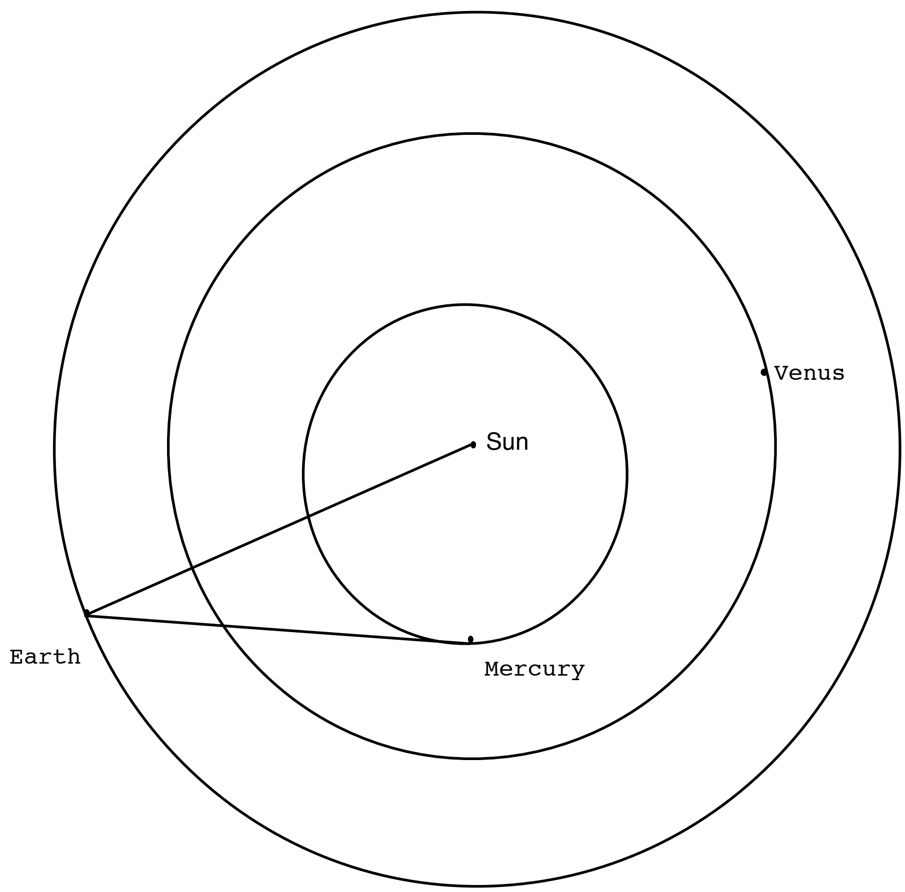
When the Earth is here, we see Mercury at one of its greatest elongations, or furthest angular distances from the Sun. This is possible four times during Earth's orbit, but only one example is shown in Figure 1.

When Mercury is at perihelion, its greatest elongation is 18°. That means the angular distance in the sky between Mercury and the Sun is 18°. That's about the same angular distance as exists between Rigel and Betelgeuse (the two brightest stars) in the constellation Orion. That's also about the same as the angular length of the handle of the Big Dipper.

Below, a diagram shows Mercury at aphelion, its furthest distance from the Sun. This is the second of four possible orientations where Mercury can be seen at a maximum elongation. Again, a line has been drawn from Mercury’s aphelion to the Earth’s orbit, showing where the Earth is located when Mercury experiences its greatest elongation at aphelion, which is 28°. That’s about the distance from the tip of the handle to the tip of the bowl of the Big Dipper.

From Earth’s perspective, as Mercury orbits the Sun, it can be seen either to the left or the right of the Sun periodically, and the maximum angle from the Sun along this apparent path is always somewhere between about 18° and 28°. Obviously, the most favorable time for naked eye observations of Mercury occurs when its angular distance from the Sun is maximized.

Notice that if a planet is at maximum elongation, if you draw a line from the planet to Earth, that line will make a right angle with a line from the planet to the Sun.



Monitor the motion of the Earth and Mercury, changing the date when necessary, and answer the associated questions below.

Set the date in the simulation for January 1 of next year.

What is the first day after this date that...

Mercury will be at inferior conjunction? _______________________

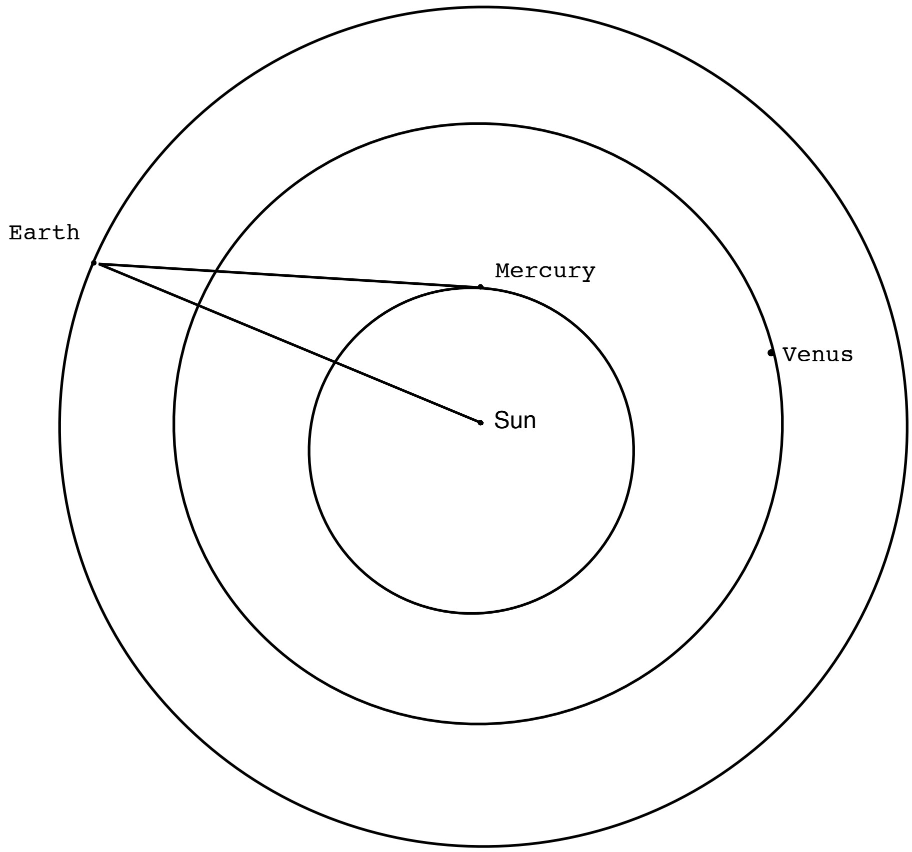
Mercury will be at maximum elongation? ________________________

Mercury will be at superior conjunction? ________________________

What is time interval (in days) between consecutive inferior conjunctions? This is Mercury's synodic period. __________________________

What is the time interval (in days) of Mercury's orbit? For example, how long is the time interval starting from perihelion to its next appearance at perihelion? This is the sidereal period. _______________________

On the diagram below, show all four possible Earth-Mercury configurations that result in elongations at either perihelion (18°) or aphelion (28°). Ask your TA for help if necessary, but it is better if you try (in pencil) first to see if you understand.



Next, think about the direction of orbital motion and rotation (both counterclockwise) for the Earth. For each of your four configurations, label whether Mercury would appear in the morning (before sunrise) or in the evening (after sunset). To get you started, the first configuration shown would be "evening".

Finally, use the mouse to drag on the screen so that it rotates downward. This has the effect of rotating your view of the planetary orbits until you get an edge-on view. Notice the orbits are all nearly coplanar. Mercury's orbit (red) is tilted with respect to Earth's orbit (green) by an angle of 5°. That's coincidentally the same angle our Moon's orbit is tilted compared to the Ecliptic!

Step 3

Now we will study the apparent motion of Mercury in the sky as seen from the Earth. Although Mercury’s maximum possible elongation of 28 degrees seems like a pretty big angle on the sky, Mercury can be difficult to see.

First of all, it is only visible to the naked eye when the sun is just below the horizon (before sunrise or after sunset), and so the sky in that direction is still fairly bright. The longer you wait, the darker the sky gets, but also the lower in the sky Mercury goes so that atmospheric effects (which make Mercury dimmer and redder) increase.

Also, just because the angular separation of Mercury and the Sun is as much as 28°, that does not mean Mercury is 28° above the horizon at sunrise or sunset! To help you understand why, we need to set up Starry Night in a certain way.

- Hit the “Home” button near the center of the top bar, just beneath the “Viewing Location” box.

- Close the SkyGuide tab.

- Open the Options tab.

- Under “Guides,” select “Ecliptic Guides”, then check “The Ecliptic”.

- Under “Local View”, uncheck “Daylight”.

- Under “Solar System”, uncheck “Asteroids” and “Comets”

- Under “Solar System”, check the Labels box for Planets-Moons

- Under “Solar System” click on the actual words “Planets-Moons” to open up an options box. At the bottom of this box, check “Label only planets bright than” and move the slider to a magnitude of about 4.

- Under “Solar System”, uncheck “Satellites” and “Space Missions”

- Now drag the sky around until you are looking at the <u>Western</u> horizon.

- Use the "Options" menu at the top of your screen. On this menu, scroll down to "Other Options" and from that menu, select the top choice, "Local Horizon..."

- On the "Local Horizon..." screen, select "Flat" horizon.

- Set the time to sunset on January 1 of next year.

At this point, you may want to ask your TA to double-check your screen to ensure your settings are all correct.

The green line that passes through the Sun and has monthly labels on it is the ecliptic. It serves as the apparent annual path of the Sun in the sky. On your screen, the Sun is in the "Jan" part of the ecliptic. As the year progresses, it will move to the "Feb" part, the "Mar" part, etc.

But it also marks out the plane of Earth's orbit. Remember that Mercury's orbit is tilted with respect to Earth's orbital plane by 5° (we saw that in the edge-on view of planetary orbits). That means Mercury will always be found close to the ecliptic.

Now pay attention to the <u>angle</u> the ecliptic makes with the horizon. Set the time flow rate to "1 day" and run time forward, watching the angle the ecliptic makes with the horizon throughout the year. <u>In the space below, note during which month the ecliptic makes the steepest (largest) angle with the horizon and which month the ecliptic makes the shallowest (smallest) angle with the horizon</u>.

During which month does the ecliptic make its steepest angle with the horizon?

____

During which month does the ecliptic make its shallowest angle with the horizon?

____

The best time to see Mercury will be during a month when the ecliptic makes a steep angle with the horizon, as shown in below in Figure 3.

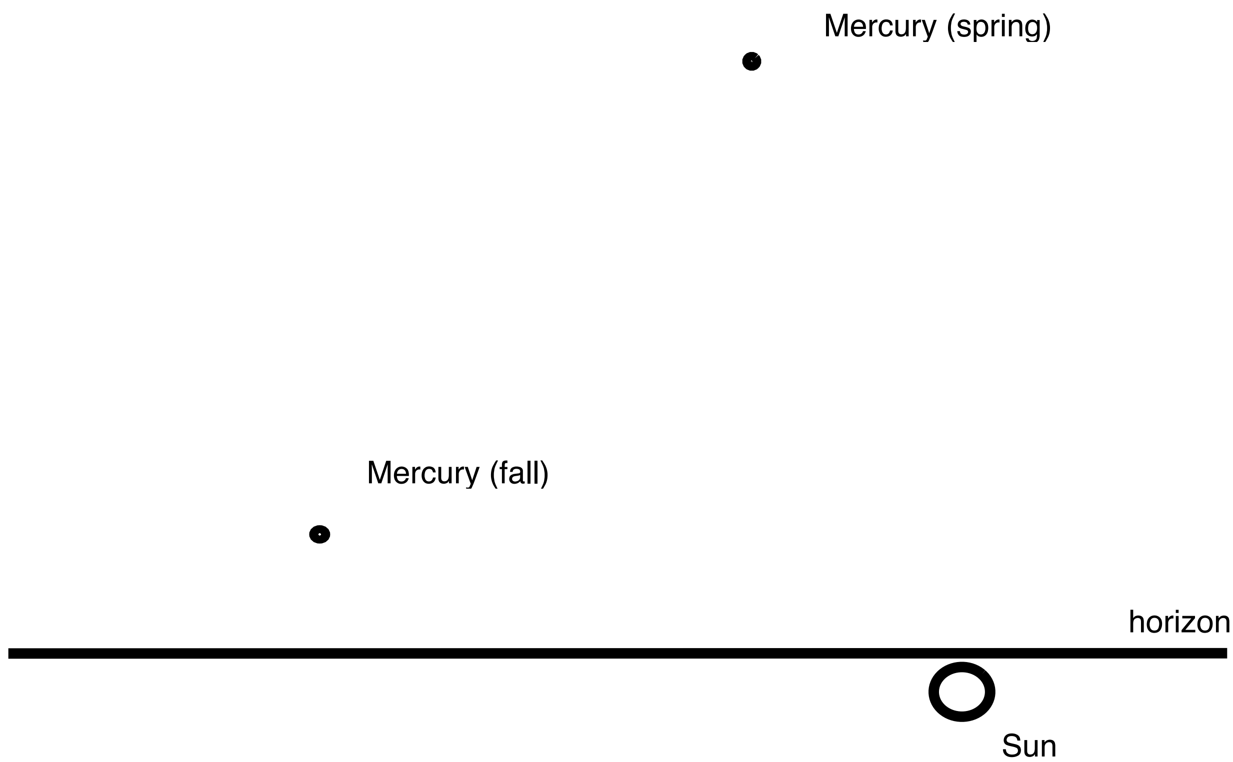


Figure 3

During Spring, when the ecliptic makes a steep angle with the horizon, it is possible for Mercury to appear very high in the Western sky at sunset. During Fall, when the ecliptic makes a shallow angle with the horizon, even if Mercury is at a large angular distance from the Sun, it won't be very high above the horizon and so not very easy to see.

Thus, the best time to view Mercury is during the Spring.

Now a few more quick steps so we can see another interesting effect.

- First, under the “Options” menu on the top bar, select “Orbit/Path Options...”.

- On this screen, check the box near the top marked “Use infinite path length”

- There is a slider below the “Show circular markers” box. Slide this to the smallest value possible (1).

- Uncheck the box near the middle that says “Show date/time”. Then close the box.

- Set the time to sunset on March 21 of next year.

- Make sure the time flow rate is set to “1 day”

Now run time forward. As soon as the planet Mercury is visible above the horizon, stop the time flow and right click on Mercury. This brings up a long menu, and about 2/3 of the way down, select “Local Path”.

This will show Mercury’s day-to-day path across the sky, as though you were observing and carefully marking its position on a star chart every day at sunset, just like the ancient Mayans, Egyptians or Babylonians once did. You will notice Mercury’s path across the sky has two very distinct shapes, a shorter path and a longer path. Stop the simulation after Mercury has completed each of the two paths once.

<u>Sketch the shapes of these two paths on the next page</u>.

Sketch the shorter path of Mercury across the sky after sunset in the space below.

horizon

Sketch the longer path of Mercury across the sky after sunset in the space below.

horizon

After you are finished, you may want to see the simulation run for a while so that you can see the patterns of these two paths over the course of many years.

Physics 10263 Lab #7:
<u>Venus</u>

<u>Introduction</u>

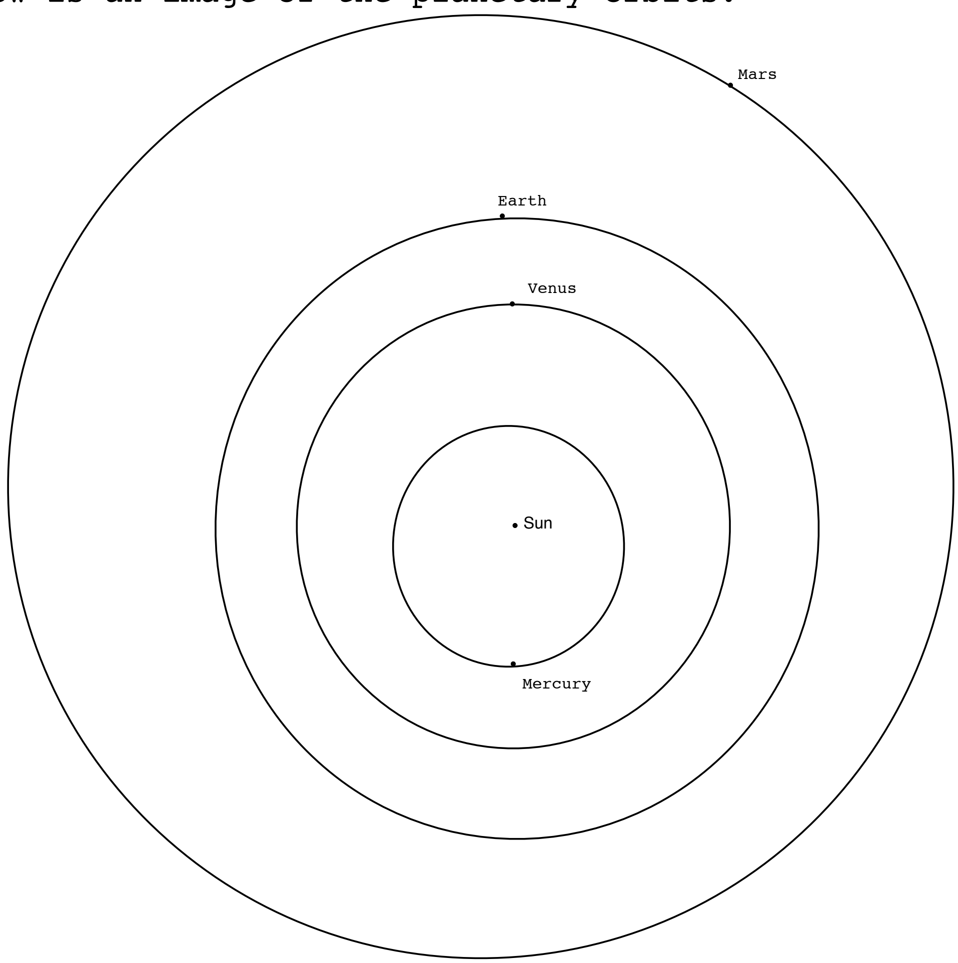
Today we will explore the motions in the sky of the brightest planet in our sky: Venus. Because of its brightness and easy visibility near sunrise and sunset, Venus played an important role in the mythologies of many cultures.

<u>Step 1</u>

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises". Select "C: The Planets". This will open a list of exercises. Open "<u>**Exercise C1:** The Inner Planets of the Solar System</u>" and from here, exercise "<u>Part 1: Orbits of inner planets.</u>"

<u>Conjunctions</u>

Below is an image of the planetary orbits.



This image shows Venus in "inferior conjunction" between Earth and the Sun. It also shows Mercury in "superior conjunction" directly behind the Sun as viewed from the Earth.

Set the date for January 1 of next year. Find the first day after this date that...

Venus at inferior conjunction: _______________________________

Venus at superior conjunction: _____________________________

Venus inferior conjunction (2nd time): __________________________

To find Venus' synodic period (in days), we need to count the days between inferior conjunctions, but this is difficult using the month and day system. Instead, we will use the Julian calendar, which just counts the days from Jan 1, 4713 BC.

Stop the clock from running and set the date back to the first inferior conjunction of Venus, then use the drop-down menu next to the date display on Starry Night. You will see a menu function "Set Julian Day...". Select this, and a box will appear showing you the Julian date corresponding to this day on the calendar. Don't worry about the fraction after the decimal.

Julian Day for 1st inferior conjunction: ________________________

Julian Day for 2nd inferior conjunction: ________________________

Difference = synodic period (in days): _______________

Step 2

Recall from our study of Mercury's orbit, there are two places where the planets cross through the Ecliptic plane: the ascending node and the descending node. The descending node is marked with a hollow half-arrow for each planet. This is where the planet is plunging down through the plane of the Ecliptic. On the opposite side of the planet's orbit (on the screen but not shown on paper) is the solid half-arrow which marks the ascending node.

Set the date for January 1 of next year, and run time forward until Venus first reaches a node.

Planetary transits can occur when the planet is at a node at the same time it is lined up with the Earth and the Sun. Below, <u>for the planet Venus, write down which months of the year it is possible to see a transit of this planet from the Earth</u>. This answer doesn't depend on the year.

What are the next two dates on which Venus will be at a node?

______________________ and _______________________

The closest transit to our date occurs from our perspective during the afternoon of June 5, 2012. To view this from TCU, make the following changes to the settings:

- Under the location box on the top bar, select "Home"
- Change the date and time to 4pm on June 5, 2012
- Scroll around the sky to find the Sun and zoom in until you can see the surface features clearly.
- Right-click on the Sun and select "Centre".
- Open the options sidebar. Under "Solar System", check the "Labels" box next to "Planets-Moons".
- On the top sidebar, increase the time flow rate to 300x and run time forward until the transit of Venus begins, when the disk of Venus first touches the Sun.
- Note the time of this beginning on your worksheet, to the nearest minute.
- Next to the Location box in the top bar is a dropdown menu. Use this to change your viewing location to Papeete, French Polynesia, also known as Tahiti.
- Again, find and center on the Sun and determine the time (in Universal Time) of the beginning of the transit.

Beginning of 2012 Venus transit from TCU: __________________

What time is this in “Universal Time”?
(see dropdown menu next to time box): __________________

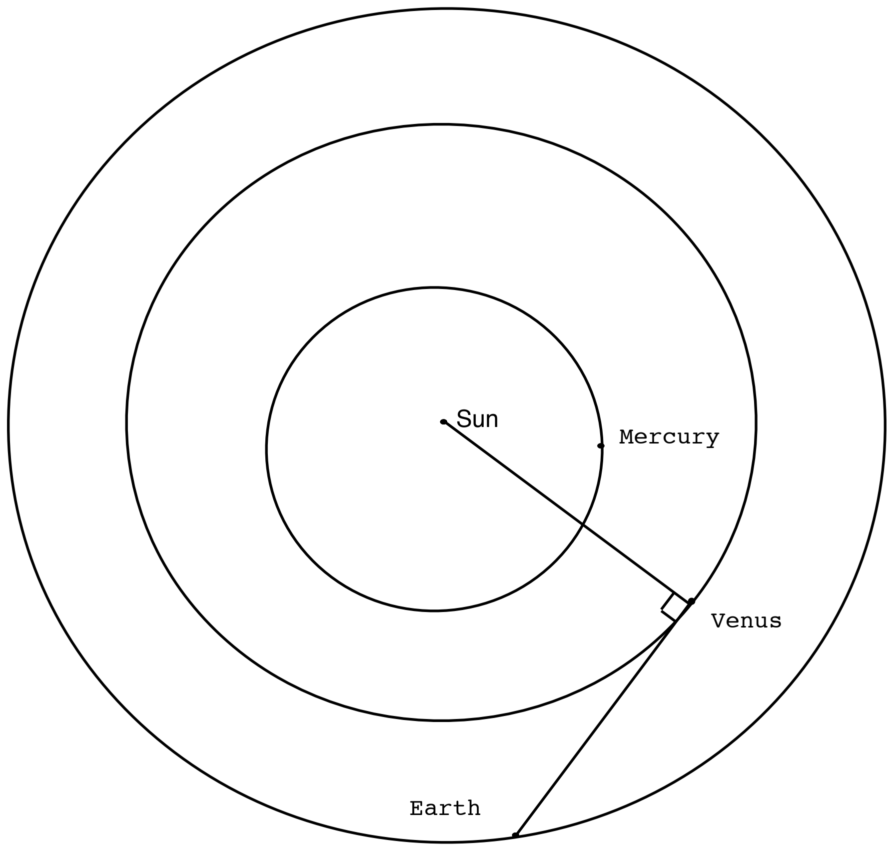
What time is the beginning of the 2012 Venus transit in Papeete, French Polynesia (UT)? ________________

The reason for this difference is parallax. Because these two places on Earth are separated by thousands of miles, they see this event at different times. This time difference proved to be important in establishing the size scale of our solar system for the first time in 1769, a historical event we will return to later.

Step 3

As with Mercury, we will study the maximum elongations of Venus. Since the orbit of Venus is roughly circular, like Earth’s orbit, the maximum elongation angle that Venus experiences does not vary much like Mercury’s elongation angle. Also, since Venus is further from the Sun, it can appear further away (in an angular sense) in the sky. Thus, before sunrise or after sunset, Venus can be found much higher in the sky compared to Mercury.

We will now explore some upcoming elongations, times when Venus will be easily visible in the morning or evening. On the next page is an example of a planetary configuration where we on Earth are seeing Venus at a maximum elongation.



Notice at this time, that a line from Earth to Venus forms a right angle with a line from Venus to the Sun. Reopen the skyguide simulation and look for the next occurrence of maximum elongation after June 5, 2012.

Open the Skyguide tab on the sidebar, then select the top option, "Student Exercises".

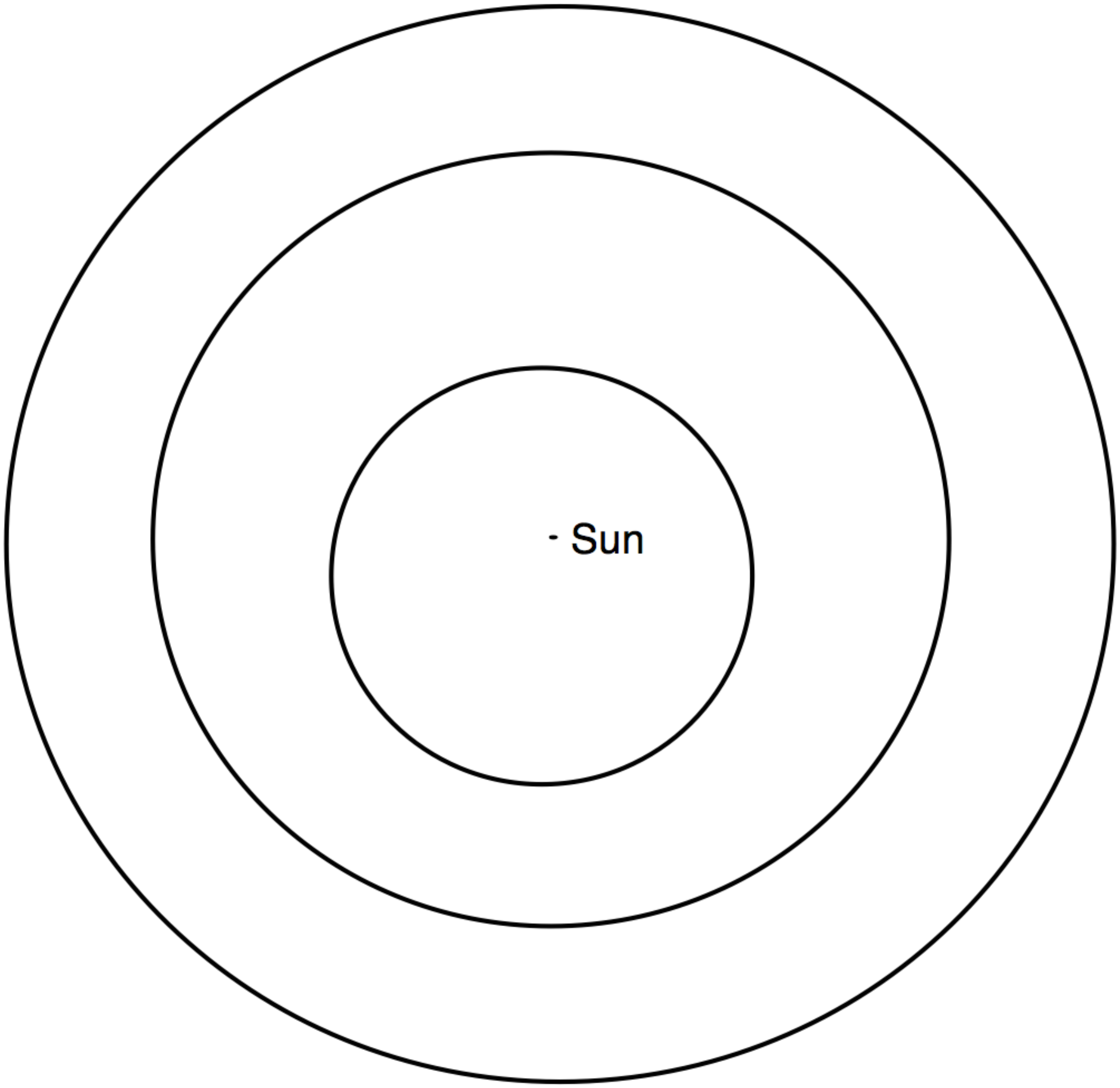
Select "C: The Planets". This will open a list of exercises.

Open "<u>**Exercise C1:** The Inner Planets of the Solar System</u>" and from here, exercise "<u>Part 1: Orbits of inner planets.</u>"

Under the Time control box on the top bar, select "Now".

Run time forward (1 day time steps) until the next occurrence of maximum elongation. <u>Sketch the location of the planets on your worksheet and note the date</u>.

On the chart below, mark the locations of Earth and Venus during the next occurence of maximum elongation.



What is the date of this elongation? ______________________________

Keeping in mind that Earth orbits and rotates in a counterclockwise direction, will Venus be visible before sunrise on this date or after sunset? ______________________________

Now use the "Home" button on the top bar to return to our standard sky view from TCU.

Set the date for the maximum elongation date you already determined and the time to sunrise or sunset, depending on when you think Venus will be visible above the horizon. Now determine Venus' altitude above the horizon by right-clicking on Venus and selecting "Show Info" at the bottom of the drop-down menu.

What is Venus' altitude above the horizon at sunrise or sunset on this date? ______________________

The next time Venus will have its maximum elongation at this time of day will be one synodic period later. You calculated the synodic period of Venus in step 1. <u>Use the "Julian Day" setting for the date to add one synodic period to today's date and again determine Venus' altitude at sunrise or sunset on this new date</u>.

What is Venus' altitude above the horizon at sunrise or sunset one synodic period after its first maximum elongation? ______________________

<u>Step 4</u>

You probably found that your two altitude answers weren't quite the same. That's because Venus doesn't follow the same apparent path in the sky at every elongation. It varies because the orbits of Earth and Venus are not exactly circular, and their perihelion points don't quite match up.

The Mayans noticed this, but they also noticed that while the appearance of Venus in the sky differs from year-to-year, there is a point at which it begins to repeat. We are going to try to recreate these observations to deduce when the cycle of Venus repeats itself. This cycle was recognized by not only the Mayans but also several other early cultures, as indicated by their writings and artwork.

Take the following steps to view the motion of Venus in the evening sky.

- Scroll around to view the Western horizon

- Set the date to the Vernal Equinox (March 21) of this year.

- Set the time to sunset.

- On the top menu bar on your screen, select “Options...” and from this menu select “Other Options” and finally from that menu select “Local Horizon...”

- In the dialog box, select “Flat” for horizon style

- Now open the options sidebar.

- Under “Local View”, uncheck “Daylight”.

- Under “Solar System”, uncheck “Asteroids” and “Comets”

- Under “Solar System”, check the Labels box for Planets-Moons, then click on the actual words “Planets-Moons” to open up an options box. At the bottom of this box, check “Label only planets bright than” and move the slider to a magnitude of -2 (brightest choice).

- Under “Solar System”, uncheck “Satellites” and “Space Missions”

- Zoom in or out as necessary until the SW and NW labels on your horizon are at either edge of your screen.

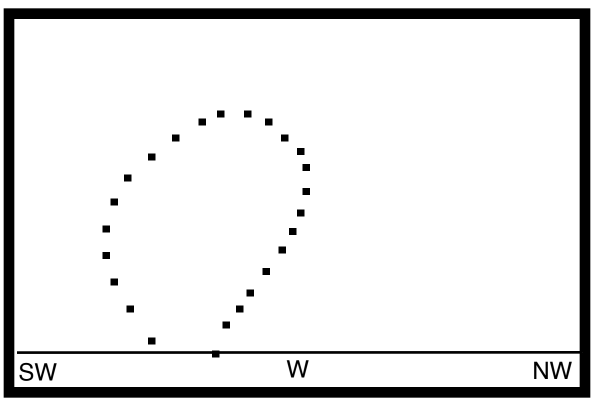
- Set the time step to one day.

- If Venus is already visible, take note of its position. If not, run time forward until Venus is visible above the horizon at about sunset.

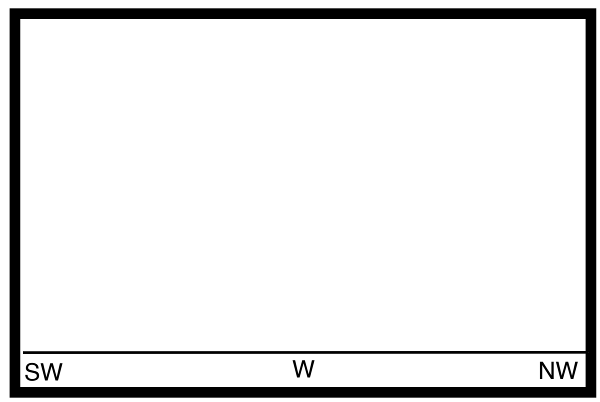
Your goal here will be to map out the day-to-day location of Venus after sunset. You will find it makes a distinctive path in the sky with each cycle. Below, there are several blank diagrams where you should draw the path of Venus through the sky. One example, showing the path of Venus in the sky starting on Feb 11, 2010, has been done for you. You may wish to check this one yourself to see Venus’ motion on the screen and how that translates to your diagram.

Starting from the next time after Feb 11, 2010 that Venus appears above the Western horizon at sunset, plot the apparent day-to-day path of Venus in the Western sky at sunset until you notice a repetition of the cycle. I recommend a dot on your diagram about every 10 days, then draw a line through the dots when you are done. You should start to notice a repetition before you run out of diagrams! Once you notice a repetition, you only need to draw the first two diagrams of the next cycle.

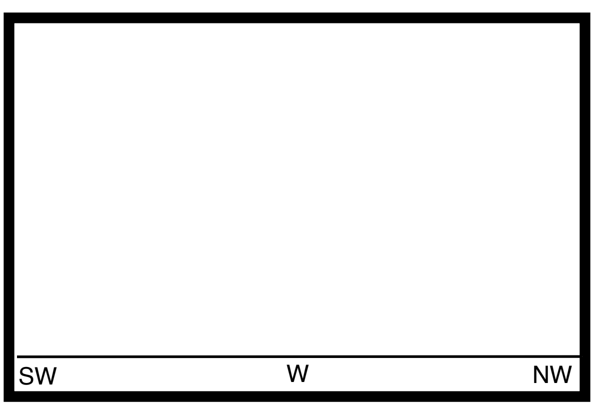
On the diagrams below, plot the day-to-day path of Venus in the Western sky at sunset. The first one has been done for you. Below each diagram, note the start date for your path. These dates should be roughly one synodic cycle apart.



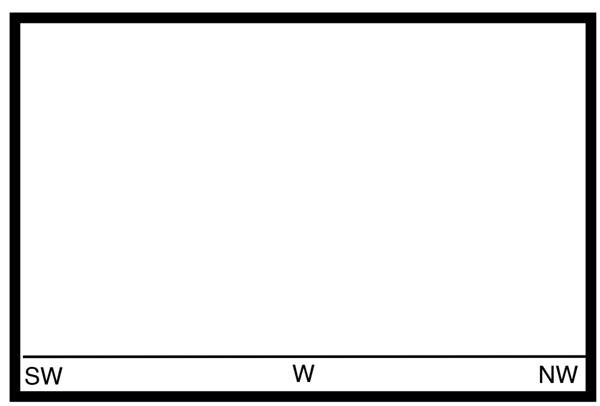
Start date: _Feb 11, 2010________



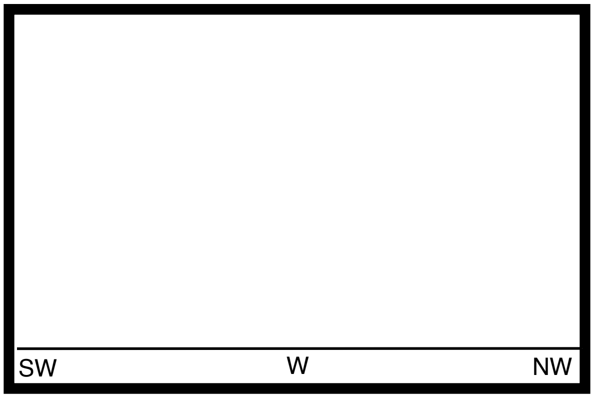
Start date: ____________________

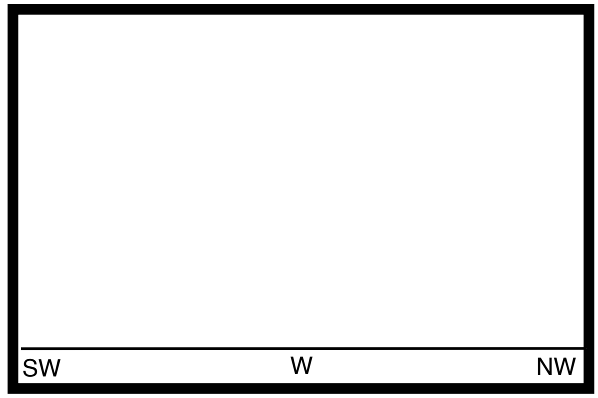


Start date: ____________________

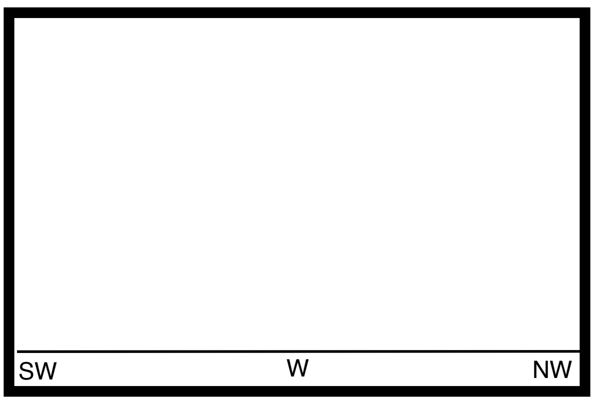


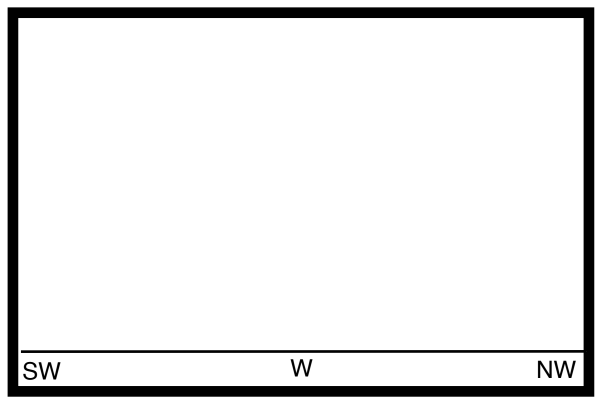
Start date: ____________________





Start date: ____________________ Start date: ____________________





Start date: ____________________ Start date: ____________________

Based on your charts, how many times does Venus appear before its path cycles back to the first path in the cycle? ________

How many years passes between the beginning of these two cycles? ________

How many days are in this number of years? ________

How many synodic cycles is this (previous answer / 584)? _______

Step 5

Like Mercury, Venus shows phases. When Galileo first noticed this through his telescope, he used it to bolster his argument that the planets orbit the Sun rather than the Earth. If you would like to center and zoom in on Venus at some point in its motion in the sky, you can see these phases for yourself as Galileo saw them through his telescope.

Later, Johannes Kepler would expand on this idea, as well as the work of Nicholas Copernicus and Tycho Brahe, to formulate his Three Laws of Planetary Motion. For the first time, planetary motions were starting to make sense to scientists and, most importantly, they were predictable through mathematics with remarkable precision.

The final piece of the planetary motion puzzle, the actual distance between the planets, was established with the help of Captain James Cook's observation of a transit of Venus in 1769. Google "James Cook Venus Transit" and read the first article that comes up (from NASA Science News) to answer the questions below for this final section of the lab.

If Cook's mission had failed in 1769, when would the next transit of Venus have occurred? ________

Explain why it is difficult to precisely determine the time of the beginning (or the end) of the Venus transit.

Did Cook make it back to England? What happened to his crew?

Physics 10293 Lab #8:
The Outer Planets

Introduction

Today we will explore the motions in the sky of the outer planets that are easily visible to the naked eye: Mars, Jupiter and Saturn.

Step 1

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises". Select "C: The Planets". This will open a list of exercises. Open "Exercise C1: The Inner Planets of the Solar System" and from here, exercise "Part 1: Orbits of the inner planets."

When one of the outer planets is directly on the opposite side of the Earth from the Sun, we call this opposition. During this time, the planet and the Earth are at their smallest distance from one another, and the planet is therefore at its brightest in our nighttime sky, high overhead at midnight.

The simulation "Part 1: Orbits of the inner planets" begins during September, 2009. Starting from this time and going forward, find the approximate dates of the next five oppositions of Mars. You may want to change the rate at which time flows to speed up this part of the lab. Remember, during opposition, you should be able to draw a straight line from the Sun, through the Earth, to Mars.

Opposition #1 date: ______________________________

Opposition #2 date: ______________________________

Opposition #3 date: ______________________________

Opposition #4 date: ______________________________

Opposition #5 date: ______________________________

What is the approximate average interval, in years and months, between successive Martian oppositions? This is the Martian synodic (solar) period.

_________ years __________ months

Step 2

You may have noticed that during Opposition #5, the Earth and Mars were much closer together than during earlier oppositions. Since Mars has an elliptical orbit, such close approaches will occur when Mars is near perihelion (the little notch marked in its orbit), its closest approach to the Sun.

In fact, the closest approach recently occurred on August 27, 2003. Set the date to this day to see where Mars was with respect to the Earth on that day.

Every time Mars has an opposition (especially back in August 2003), we are typically bombarded with messages about Mars being "huge" or "the size of the full moon" as if this is some sort of amazing record or incredible and unprecedented visual phenomenon, but actually, Mars doesn't look all that different at various oppositions. Its brightness and apparent size depend on the distance from Earth to Mars at the time of opposition.

Use the "Home" button to return to Fort Worth and set the date for the first opposition date recorded above. Set the time to 11pm, then use the "Find" sidebar to find Mars. Once you see Mars on your screen, hover your cursor over it to determine the distance from Earth (observer) to Mars.

Repeat this for each of the opposition dates we studied in Step 1 and record the information below (round off to three digits). Note that "au" for distance means "astronomical unit" which is the Earth-Sun distance, approximately 93 million miles.

Earth-Mars distance for Opp. #1: ________________ au

Earth-Mars distance for Opp. #2: ________________ au

Earth-Mars distance for Opp. #3: ________________ au

Earth-Mars distance for Opp. #4: ________________ au

Earth-Mars distance for Opp. #5: ________________ au

Earth-Mars distance for Aug 27, 2003: ________________ au

% difference between Aug 27 and other close opposition: ________

The 5th opposition represents a "typical" minimum opposition. The Earth-Mars opposition occurs near the Martian perigee about every 9th or 10th opposition. The August 27, 2003 opposition was heralded by many as something incredibly special, but in reality, it wasn't much different from an ordinary opposition near perigee.

On your worksheet, calculate the percentage difference in distance 100 * (difference) / closest distance, which shows in percentage terms, this opposition wasn't much different than most other oppositions of this kind.

In order for Mars to truly appear to be "the size of the full moon" in the sky, its distance from Earth would have to be about 0.004 au, not 0.372 au!

Step 3

For this part of the lab, we will go to another Skyguide exercise. Open the Skyguide tab on the sidebar, then at the top of that window, where it reads "Student Exercises >> C - The Planets >> C3 - Direct and Retrograde Motion of the Planets."

From there, click on exercise "1: Direct motion." Run time forward several seconds so that you can watch the "direct" motion of the planets. If you let the time go for longer than that, you will notice Jupiter beginning a retrograde loop. Most of the time, planets tend to travel at a roughly uniform speed along the ecliptic toward the East. That means if we map the planets against the background stars, they will seem to move a tiny bit further east each day.

Now click on exercise "2: Retrograde motion".

Right-click on Jupiter and select "Local Path" from this menu.

Run time forward until you see Jupiter complete a retrograde loop, a short time interval where it seems to reverse course and go opposite of its normal easterly motion along the ecliptic. We're going to try to understand this motion a little better.

It is easier to see and draw the retrograde motion for Mars, so we are going to make a couple of adjustments to the exercise.

- Right-click Jupiter again and unselect "Local Path"

- Open the Find sidebar. Uncheck Jupiter and Saturn, then check Mars.

- One retrograde loop of Mars will occur starting in early 2012, so let's set the time in the simulation to November 1, 2011 at 11:00 AM.

- Set the time flow rate to 10 sidereal days.

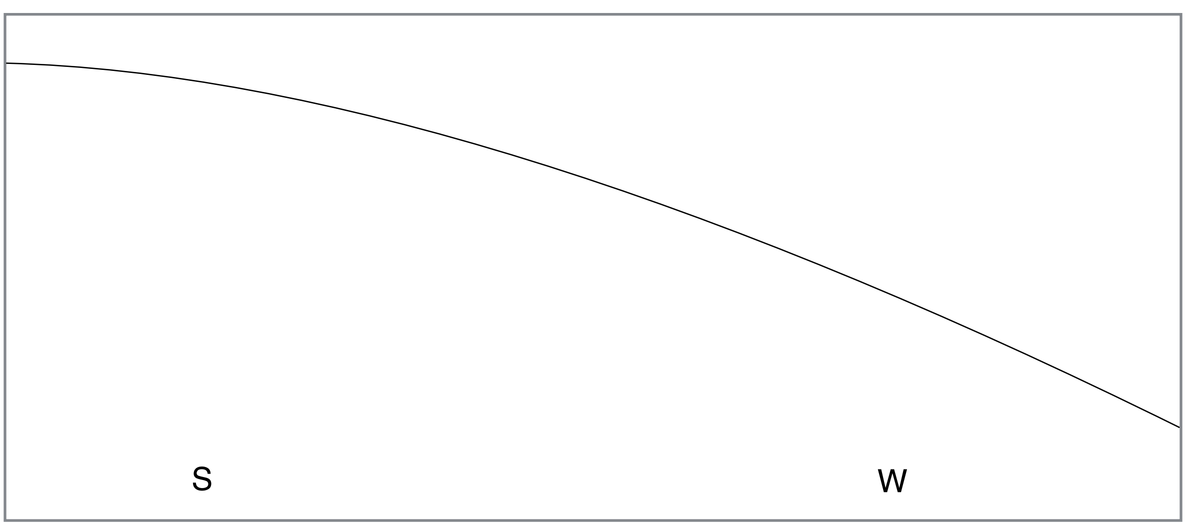
- Right-click Mars and turn on "Local Path." You may want to zoom in a little bit to make it easier to select Mars (see box below and use the "S" and "W" labels for zoom reference).

- On the TOP menu bar, open Options and "Orbit / Path Options..."

- In this dialog box, do the following:
    - Set the program to mark every 3 steps
    - Uncheck "Show date/time"

- Step time forward **MANUALLY** (one click per 10 days, otherwise, it will go way too fast for you to follow) enough times until you reach July 27, 2012.

- Below, make a sketch of this retrograde loop of Mars, marking every 30 days (every 3 steps) with a small dot and the date (month/day). The green ecliptic line has already been drawn for you for reference.



Now go back to “C - The Planets” in the title part of the skyguide sidebar.

Next, click on “C1 - The Inner Planets of the Solar System” and from there, click on exercise “1: Orbits of inner planets.”

We’re going to focus first on the orbit and motion of Mars, so zoom in until Mars’ orbit nearly fills the screen, keeping the Sun near the center as best you can.

- Stop time from flowing. It is too distracting.

- Open the Find sidebar and uncheck the boxes to the left and right of Venus and Mercury.

- Set the date to the beginning of our drawing of the retrograde loop: November 2, 2011 at 11:00 AM.

- On the diagram on the next page, draw dots at the approximate location of Earth and Mars every 30 days. For each pair of dots, draw a line from the Earth, through Mars, that ends near the left hand side of the page near the vertical reference line, like the example shown for the first date. The first, fifth and ninth locations of Earth and Mars have been drawn for your reference, along with their respective dates.

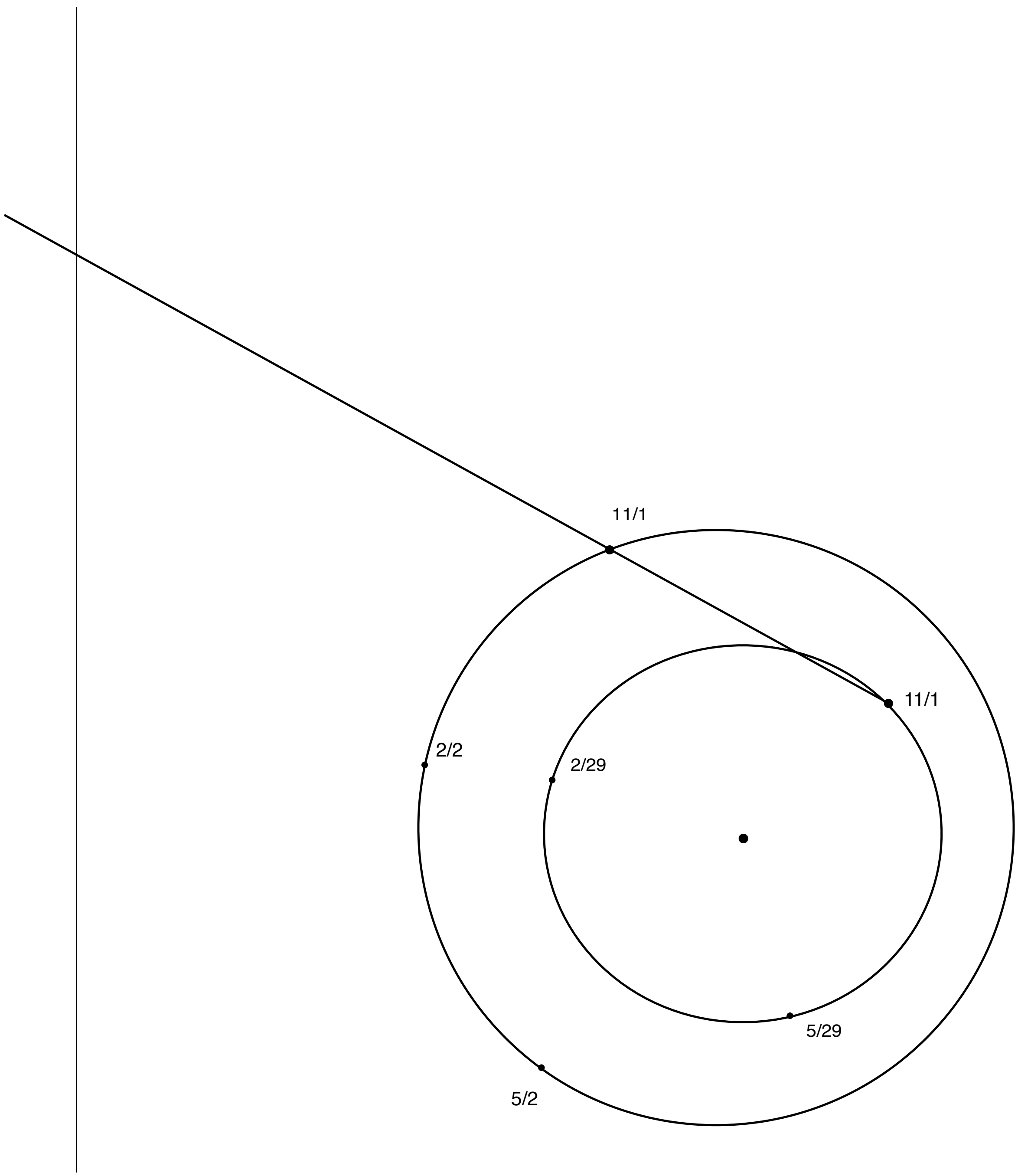
- Where each of your Earth-Mars lines crosses the reference line, write a small number, starting with 1.

- Draw a line through the endpoints of your lines, and you should see the motion of Mars go through the same loop that you drew previously.

This is the reason that planets undergo retrograde loops, a process that confused skywatchers for centuries until Renaissance astronomers put forth a model for the solar system with the planets orbiting the Sun at the center.

For more background into this scientific revolution, we will use some of the other exercises in the Skyguide.

Use the diagram on the next page of Earth’s orbit and Mars’ orbit to track the retrograde motion of Mars.


11/1
11/1
2/2
2/29
5/29
5/2

Step 4

In the Skyguide sidebar, return to "Student Exercises" and select "B - Solar System." Work your way through exercises B1 through B4 and answer the associated questions below.

Retrograde Motion

When Mars is in the middle of its retrograde loop in Exercise "1: Retrograde motion", what is the date?

____

Based on your answers in step 1, is Mars closer to opposition or superior conjunction (lined up on opposite side of the Sun)? __________________

The Geocentric Model

According to the Ptolematic geocentric model of the solar system, a planet's orbital path around the Earth is called a…?

____

In this model, the retrograde loop is caused by the planet's turning on the smaller circular path called a ...?

____

Notice that in this model, when Mars is undergoing a retrograde loop, it is closest to Earth and therefore brightest, which matches the observations they were able to make at that time.

Inferior and Superior Planets

Use a diagram and a sentence or two to explain why Mercury and Venus are never visible at midnight.

From **Exercise B2:** Planetary Orbits and Configurations:

What is Mercury’s sidereal period? ________________ days

What is Mercury’s synodic period? _________________ days

Jupiter’s synodic period: ___________________ years

Jupiter’s sidereal period: ____________________ years

From **Exercise B3:** Johannes Kepler and Ellptical Orbits:

Mars’ perihelion distance: ______________ au

Mars’ aphelion distance: ______________ au

Major axis of Mars’ orbit: _____________ au

Does Mercury move faster when it is closer to perihelion or aphelion? ___________________

From **Exercise B4:** Galileo Strengthens the Heliocentric Model:

Use a diagram to help explain why, in the geocentric model, the phase of Venus should never be full or gibbous.

What is the phase of Venus in exercise 1? ________________

The simulation in exercise 2 shows the angular size of Venus changing as it goes through a 584-day cycle of phases. Remember, the angular size tool is on the top left (the down arrow next to the hand allows you to change tools).

What is the angular diameter of Venus (in arcseconds) when it is showing the following phases:

Full: ______________

Half lit (at maximum elongation): ____________

New: ______________

This variation in size is precisely what the heliocentric model suggested would happen and also contradicted the geocentric model.

Briefly explain why Galileo's observation of the moons orbiting the planet Jupiter went against the geocentric model.

Essay

On your own paper, think back on the labs you did this semester and answer the following questions about the eight regular labs we did this semester, which were...

1 - Using the real in-class celestial spheres.
2 - Introduction to Starry Night, motion of Sun/Moon
3 - Using Starry Night to learn about and predict eclipses
4 - Starry Night Exercises I: Coordinates, Sun and Moon
5 - Starry Night Exercises II: Phases of the Moon, Eclipses
6 - Starry Night: The Orbit and Motion of Mercury
7 - Starry Night: The Orbit and Motion of Venus
8 - Starry Night: The Outer Planets

Which regular lab (not supplemental lab) was most enjoyable for you and why?

Which regular lab was least enjoyable for you and why?

Which regular lab did you learn the most from that would potentially help you on the final exam in lecture? Explain.

Which regular lab did you learn the least from? Explain.

Physics 10293 Lab #9:
The Copernican Revolution

Introduction

Today we will explore two articles in Scientific American that cover detailed historical aspects of the Copernican Revolution. The basic story is that, for thousands of years from the first published works on the motions in the heavens, astronomers believed that the Earth was the stationary center of the Universe ("geocentrism"). For a period of about 300 years, starting in the 15th century, astronomers slowly came around to the point of view of "heliocentrism," with the sun at the center of the solar system and the Earth just one of many orbiting planets.

Why did this revolution take so long? Why did so many brilliant people believe a completely wrong model for how the Universe works? Were they just stubborn? Did religious influences prevent the free exchange and growth of ideas? Were there good scientific reasons to stick to the old model, given the available information?

The answers to these questions are closely tied to why we study the history of science: we want to learn what causes scientists to be wrong, what causes scientific revolutions and perhaps put those answers in today's context to see if we are due for another revolution in some field.

"Astronomy in the Age of Columbus"

In order to access this article, you will need to go to the Doc Sharing area for Physics 10293 on the Pearson Learning Studio site at **tcuglobal.edu**. Find the article at the bottom of the list, below the lab manual files. Read through the article and answer the following questions as you do. The questions are asked in the same order the topics are covered in the article.

<u>Q1</u>. The author asserts that most scientists of Columbus' era (late 15th century) agreed that the Earth is round. Why did many people abandon this belief in the United States after the American Revolution? Explain.

<u>Q2</u>. Columbus himself agreed that the world is round. Explain how he justified his voyage to the king and queen of Spain, to make them believe it was possible.

Q3. Although Columbus wasn't much of an astronomer, he did make use of "Ephemerides," a reference book for timing astronomical phenomena such as lunar phases and eclipses. Explain how.

Q4. Explain why Ptolemy's original geocentric model of the solar system was doubted by scholars of Columbus' era.

Q5. Explain why Copernicus' original heliocentric model of the solar system was no more accurate that Ptolemy's geocentric model.

Q6. Name and explain three different arguments or lines of evidence that helped prompt the revolutionary change in consensus from Ptolemy's geocentric model to a Copernican heliocentric model.

"The Case Against Copernicus"

Now find this article in the same place as the Columbus article, read through it as you answer the following questions, which are again covered in the same order as the article covers the topics.

Q7. Describe the cosmology proposed by Tycho Brahe with the help of a diagram. Explain why it is consistent with Galileo's observations of Venus where the geocentric model isn't.

<u>Q8</u>. Name and explain three arguments or lines of evidence described in the article that astronomers of that time felt contradicted the Copernican heliocentric model.

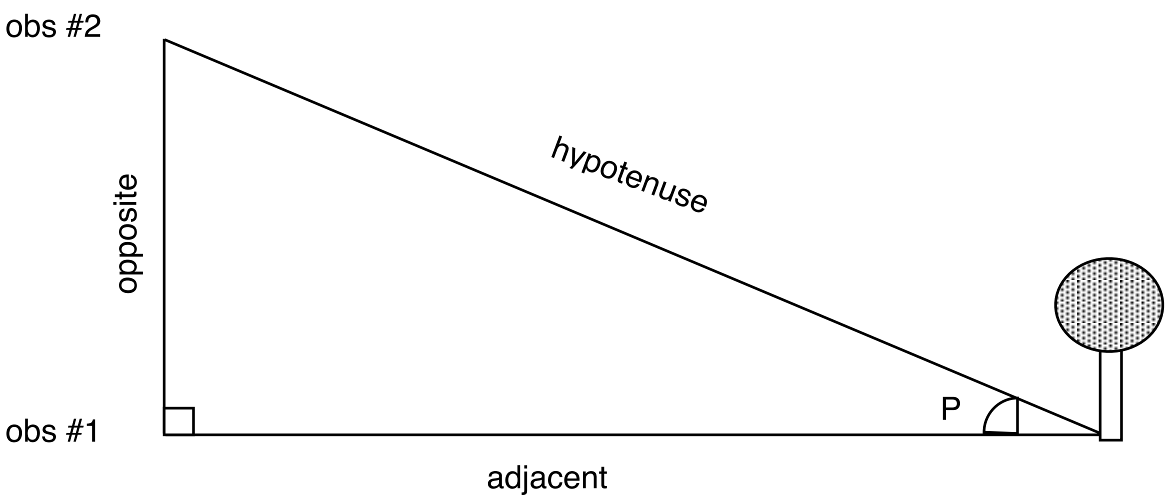
Physics 10293 Lab #10:
Stellar Parallax

Introduction

Parallax is a distance determination technique that uses geometry to measure the distance to some object when other means (such as a ruler or tape measure) won't suffice. On Earth, surveyors call this technique triangulation.

Part 1

In the diagram below, we want to measure the distance to a tree that we cannot walk to (perhaps a river is in the way). So we measure its position from two different observation points, drawing a line from each point to the tree and a line connecting our two observation points as shown below.

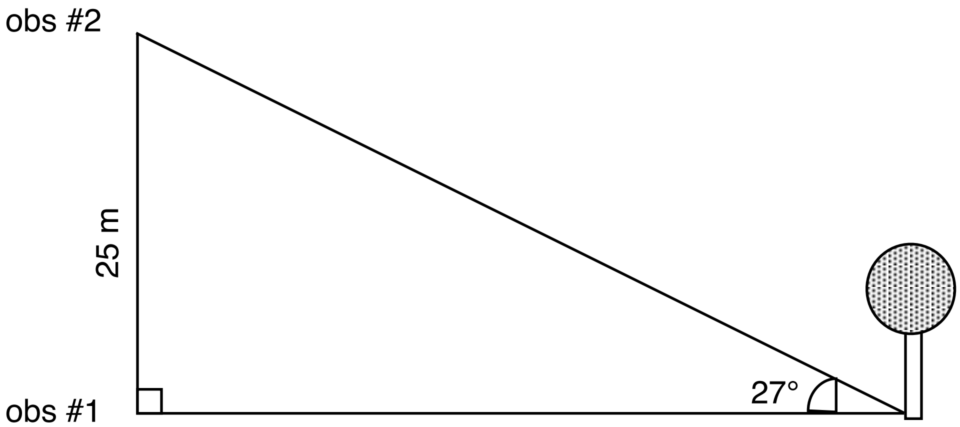


If we physically walk from observation point #1 to observation point #2, then we know that distance. Let's assume it is 25 meters. Using a protractor or other angular measuring device, we can also determine angle P. Let's assume that angle P is 27 degrees.

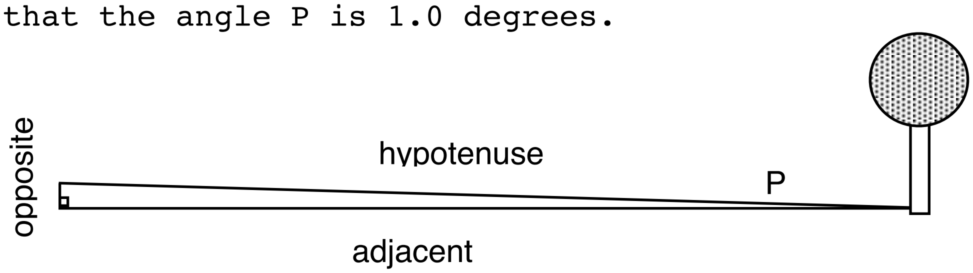
Basic geometry tells us that for angle P,

sin (P) = opposite / hypotenuse
cos (P) = adjacent / hypotenuse
tan (P) = opposite / adjacent

Determine the lengths of the hypotenuse and adjacent side of this triangle and write those values next to the corresponding sides on the diagram below.

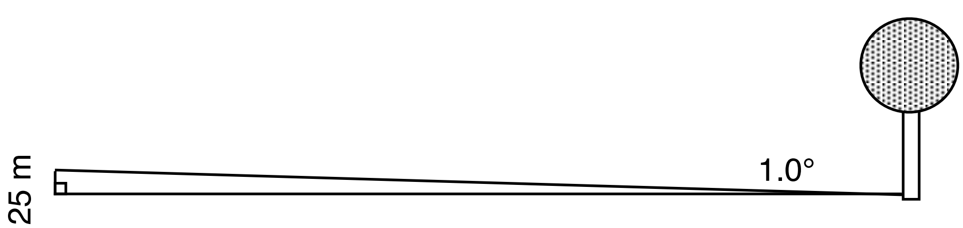


In Astronomy, the angles we measure are much smaller. On the diagram below, assume the opposite side is 25 meters and that the angle P is 1.0 degrees.



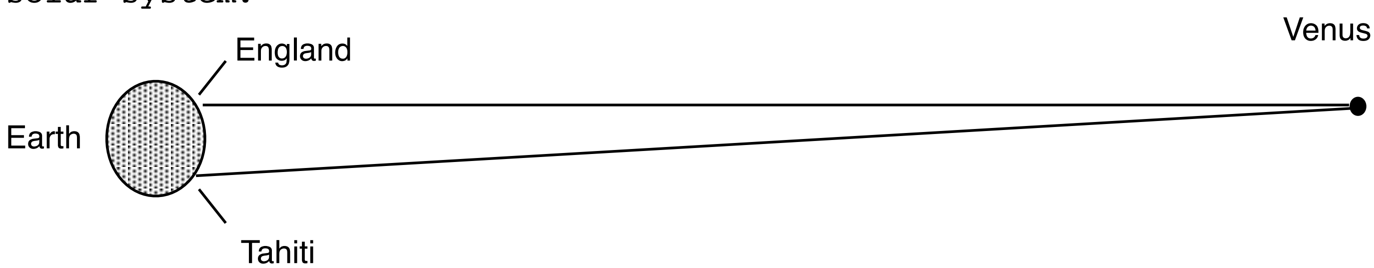
Notice that in the second case, the values for the adjacent side and the hypotenuse are nearly identical. For very small angles, this will always be the case, so it doesn't really matter in our triangle which of the two sides we calculate.

Determine the lengths of the hypotenuse (upper) and the adjacent side (lower) and fill these values in next to the corresponding sides on the diagram below.



Part 2

Historically, parallax played a significant role in our study of the solar system and our galaxy. In the earlier Venus lab, we learned about the story of Captain Cook's expedition to Tahiti. Part of his mission was to measure the timing of the transit of Venus across the Sun. While Cook was making his measurements, astronomers were also timing the transit from England. We know the staight-line distance (through the Earth) between England and Tahiti. We can also calculate the angle P (**the parallax angle**) based on the time delay between transits. We then use this information to deduce the distance from Earth to Venus and, for the first time, establish the scale of our solar system.



Prior to this, Astronomers couldn't reliably use parallax to measure the distances to planets because the positions of the planets could not be measured precisely enough from two different locations simultaneously. Even if one person tried to do both measurements with the same instruments, it took time to travel across the Earth from one observation point to another, and in that time, the planet would inevitably move on its own against the starry background, making the parallax measurement impossible.

The stars themselves, however, do not move significantly in the sky over time, and so there was some hope we could use parallax to determine how far away the stars are. Sirius is the brightest star in the sky, and astronomers (correctly) deduced that one reason for its brightness is that it is closer to the Earth than most other stars.

A quick aside about angular measurements: for small angles, we do not use degrees but instead arcminutes and arcseconds.

1 degree = 60 arcminutes = 3600 arcseconds.
1 arcmin = 0.167 degrees

1 arcsec = 0.000278 degrees

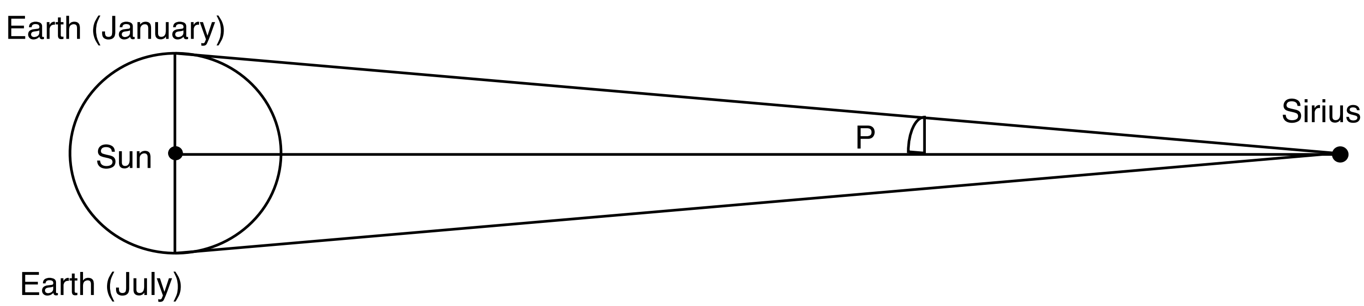
Attempts were made to accurately measure the position of the star Sirius from two different locations on the Earth. Our most accurate observations at the time, however, could only measure angles as small as 1/120th of a degree, which is 30 arcsec.

Work through the example on your worksheet to determine the parallax angle of Sirius if it is viewed from two places on the Earth approximately 3000 miles apart.

Since we could at that time only measure angles as small as 30 arcsec, you can see from your answer that the parallax angle of Sirius measured in this way is about a million times too small.

Then the Copernican Revolution happened.

According to the ideas promoted by Galileo, Copernicus and Kepler, the Earth orbits around the Sun. Astronomers realized that we could use this to our advantage in measuring parallax angles.



Instead of using 3000 miles on the Earth as a baseline, we can use the radius of Earth’s orbit (93 million miles). To improve accuracy, we can even use the whole diameter of Earth’s orbit so that the tiny angle we are trying to measure is twice as big, but to keep it simple, let’s stick with the radius.

Use the radius of Earth’s orbit as your opposite side (baseline) and the distance to Sirius as your hypotenuse to determine the parallax angle of Sirius. This is the proper way to determine parallax and the method Astronomers still use today.

The distance to Sirius is 50.5 trillion miles, or 5.05×10^{13} miles. Use this for your hypotenuse and 3000 miles for your opposite side (we call this the baseline) and determine the parallax angle for Sirius in degrees and arcseconds.

P = _________x $10^{\_\_\_\_}$ degrees

P = ____________________ arcsec

Notice that your calculated parallax angle for Sirius is still much smaller than our 30 arcsecond accuracy limit. In fact, Astronomers tried in vain to measure parallax angles for many stars and were completely unsuccessful at this time. We know today that the reason for this lack of success is due to the great distances to stars (hence, extremely small parallax angles).

Redo the parallax angle for Sirius using 93,000,000 miles as your baseline distance (this uses the Earth's orbit as the baseline rather than two points on Earth). Use this to determine the parallax angle for Sirius in degrees and arcseconds.

P = _________________ degrees

P = _________________ arcsec

At the time, however, many Astronomers were unwilling to accept the idea that stars were so far away. In order for the parallax angle of Sirius to be too small to measure, they calculated that it would have to be at least 5000 times further away than the most distant planet known at the time (Saturn). From a philosophical standpoint, they thought it was absurd that God would waste so much space. They felt it reasonable to assume that the stars are much closer.

The lack of an observed parallax angle, then, would be explained by the fact that <u>Earth doesn't really orbit the Sun</u>. After all, there are two reasons a parallax angle might be small: Either the distance to the object (the hypotenuse) is really big or the baseline (the opposite side) is really small. We will explore that concept more thoroughly in part 3.

Part 3

On the diagram to your right, draw a line from Earth (in January) through star A and to the distant background stars. USE A RULER FOR A STRAIGHT LINE.

You now have a narrow parallax triangle with the radius of Earth's orbit as the baseline. The small angle just below star A is your parallax angle P, the Earth's orbital radius is the side opposite, and the distance to the star is the hypotenuse of this triangle. Label the parallax angle P_A.

On this same diagram, draw a second star (star B) on the dashed vertical line farther from the Sun than star A. Now in a different color or perhaps with a dashed line, draw a line from Earth (in January) to star B. Label the parallax angle for this star P_B.

Which star, A or B, has the larger parallax angle?

____

Consider the following two statements regarding this exercise:

#1: The parallax angle of star B should be larger because star B is further away.

#2: Star B is further away, so its triangle is sharper or narrower. That means the parallax angle is smaller.

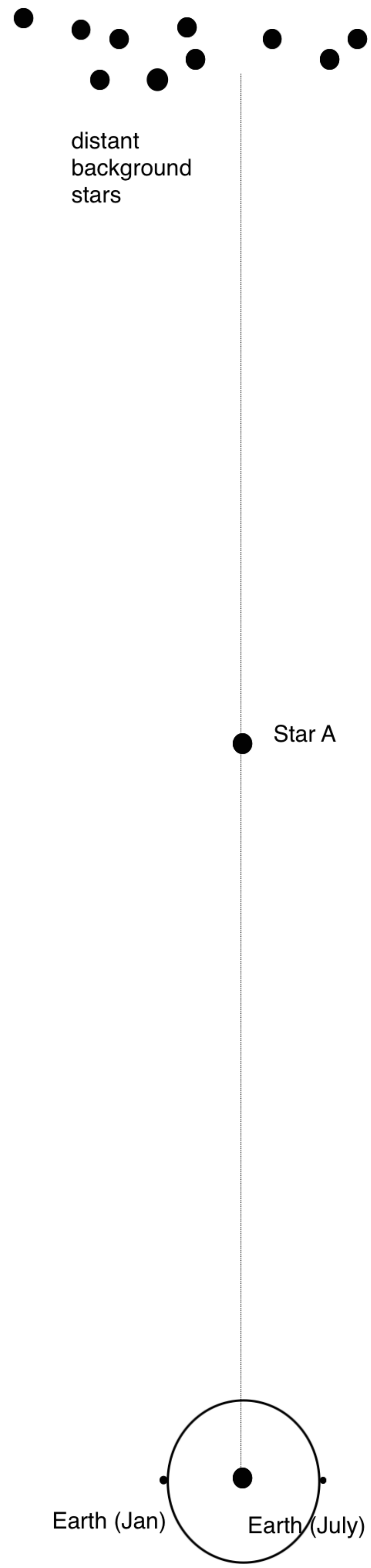
Which statement is right?

____

Consider the parallax angle of star A. If Earth's orbital radius (our baseline) were smaller, the parallax angle of star A would be

_________________.

So there are two ways to explain a star having a very small (unmeasurably small) parallax angle: either the star's distance is incredibly large or the baseline we are using is very small (about 3000 miles instead of the 93,000,000 mile radius of Earth's orbit).



In your own words, explain why Astronomers of Galileo’s era were unable to measure parallax angles for nearby stars like Sirius.

Next, in your own words, explain how they used the lack of measured parallax as a way to argue against the Copernican sun-centered (heliocentric) model in which the Earth revolves around the Sun. Instead, they used the lack of parallax to support the old Earth-centered (geocentric) model in which the Earth doesn’t move and all of the planets, including the Sun, orbit the Earth.

Physics 10293 Lab #11:
The Origin of the Constellations

Introduction

In this lab, we will study the research compiled by Ian Ridpath in his online book, “Star Tales,” to help understand the origin of the modern-day constellations. I have organized several questions about the first two chapters of this reading below and included sufficient space for you to write your answers. There will be no essay with this lab.

Chapter 1, Page 1a

(http://www.ianridpath.com/startales/startales1a.htm)

The constellations we use today were first published as a set by Ptolemy in his book known as the Almagest. Explain the two lines of evidence (one of them written, one of them having to do with the gaps in the star maps) that many of the constellations in Ptolemy's book likely originated from the Babylonian civilization that existed about 800 years prior to Ptolemy's era.

Chapter 1, Page 1b
(http://www.ianridpath.com/startales/startales1b.htm)

Describe the evidence for and against the hypothesis that the Minoan civilization centered on the island of Crete was the primary source of constellations recognized by the Greeks and Ptolemy.

Describe the role of the Arabic astronomer Al-Sufi (or Azophi) in the creation of the constellation and star names we use today.

Chapter 1, Page 1c
(http://www.ianridpath.com/startales/startales1c.htm)

Explain the origin of two large constellations in the Northern celestial hemisphere: Camelopardalis and Monoceros.

What was the role of Petrus Plancius in filling in the Southern Celestial hemisphere with 12 new constellations, previously uncharted?

Chapter 1, Page 1d
(http://www.ianridpath.com/startales/startales1d.htm)

Explain the role of Johannes Hevelius in the modern set of recognized constellations.

Explain the role of Lacaille in the modern set of constellations.

Why are there so many constellations named after scientific instruments (e.g. Telescopium, Microscopium) in the Southern celestial hemisphere?

Describe how the current officially recognized boundaries for the constellations were drawn.

Chapter 2, Page 2a
(http://www.ianridpath.com/startales/startales2a.htm)

What is the Farnese Atlas? Explain its historical significance.

What is the Dunhuang star chart? Explain its historical significance.

Explain how the themes and names of Chinese constellations differed from Western constellations.

Chapter 2, Page 2b
(http://www.ianridpath.com/startales/startales2b.htm)

What is the Uranometria? Explain its historical significance.

What are Bayer letters, and how were they usually assigned to specific stars?

Chapter 2, Page 2c
(http://www.ianridpath.com/startales/startales2c.htm)

What are Flamsteed numbers, and where did they originate?

Explain the origin of simpler line diagrams connecting bright stars on published maps as opposed to the more elaborate pictures that had been the norm.

<u>Chapter 2, Chinese Constellations (linked on page 2a)</u>
(http://www.ianridpath.com/startales/chinese.htm)

Explain how the Chinese constellations originally organized the sky. In particular, describe lunar mansions and the four-part zodiac.

Explain two reasons why it is very difficult to determine the identifications of specific stars within constellations from Chinese star charts.