Name: ___________________________
Partner(s): ________________________
1101 or 3310: ______
Desk # ____________
Date: _____________

Time Keeping

Purpose

- Build a horizontal sundial that reads the same time as your wristwatch in Vancouver

Equipment

- Cardboard
- Thick paper
- Scissors
- Compass
- Modeling clay
- Polar graph paper
- Flashlight
- Gnomon
- Pivot
- 2 small protractors
- Ruler
- Starry Night
- Calculator
- Balls

People began measuring time long before they knew that the Earth is round or that it is orbiting the Sun. They defined units of time based on the motion of celestial bodies.
Question 1: To which celestial event does each of these units relate.

a) Day:

b) Week:

c) Month:

d) Year:

The Gnomon of a Horizontal Sundial

On a sundial, the gnomon (or style) is the piece of the sundial that casts its shadow onto the sundial face. For a horizontal sundial, the gnomon must be aligned with the north celestial pole (Polaris) so that the Sun will rotate around it.

Question 2: Draw a complete and detailed bowl diagram (including N, W, E, S, Polaris, Z and latitude of the place) showing the correct orientation of the horizontal sundial and its gnomon in Vancouver. Also draw the path of the Sun on the two solstices.

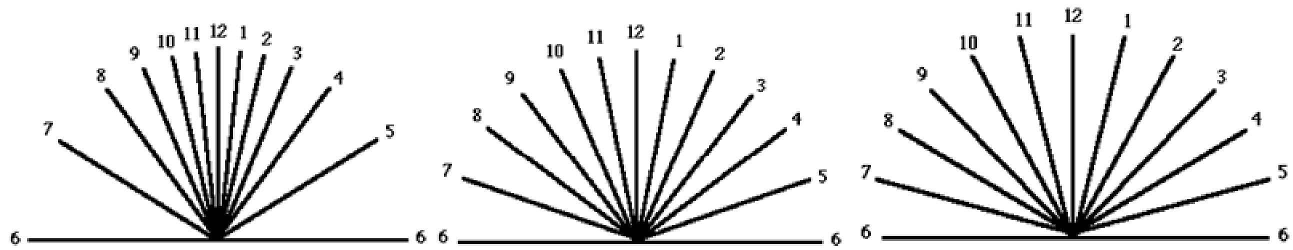
Question 3: ASTR 1101. For horizontal sundials, the graduations are not equally spaced because they are a projection of the celestial equator onto the ground and the spacing between graduations differ depending on your latitude. Explain why this is.

The Graduated Disk

Sundials can be equatorial or horizontal. In this lab, you will be constructing a horizontal sundial. The following link has more information on equatorial sundials and an explanation on how they differ from horizontal ones.

http://langaraphysics.com/Tyron/Sundials.htm

Here are the hour line graduations for horizontal sundials at 3 different latitudes.



Hour Line Markings for 25° Latitude **Hour Line Markings for 50° Latitude** **Hour Line Markings for 75° Latitude**

Question 4: Sundial. Use the polar graph paper and draw the graduation of your sundial. Ask your instructor to check your work. You only have to make 1 set of graduations.

Instructor's initials: _______________

Sundial. Once your graduations are checked, mount the graduated disk onto a rigid circle of the same size and add a gnomon to your sundial. Now, find the right orientation of your sundial using a compass.

The Analemma

Because the orbit of the Earth is not a perfect circle, if one plots the position of the Sun at noon every day over a year, the Sun is not exactly at an azimuth of 180 degrees (i.e. South). Instead the Sun is slightly shifted East or West. You already know that the position of the Sun at noon also changes due to the tilt of the Earth (up to 23.5 degrees above/below the celestial equator). Consequently in the course of a year the Sun follows a figure-8 pattern referred to as the analemma.

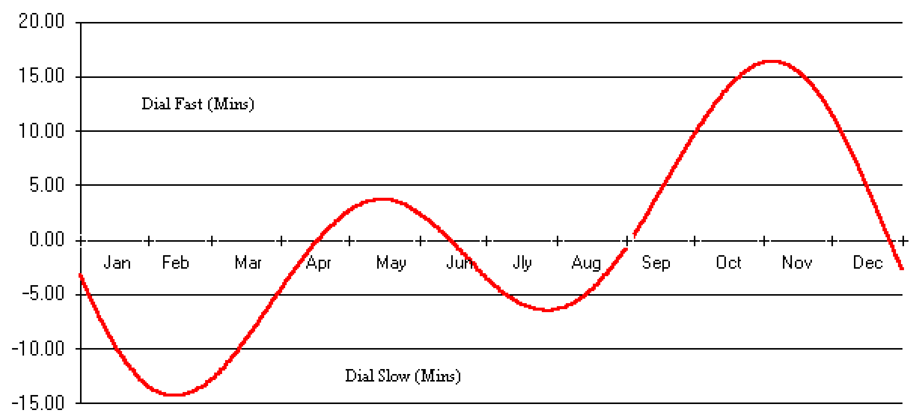
Optional: With Starry Night, watch the analemma in Vancouver (you can find it in one of the menus).

Question 5: Draw a large figure-8. Indicate which shift (horizontal or vertical) is due to the tilt of the Earth on its orbit, and which is due to the non-circular shape of the Earth's orbit.

The Equation of Time, Mean Solar Time

In the previous part we saw that the position of the Sun at noon shifts depending on the time of year because the orbit of the Earth is not a perfect circle. This also means your watch will not remain perfectly synchronized with the sundial over the course of a year. For practical purposes it is convenient to define a time in terms of the average of the apparent solar time. This is called the mean solar time and is the basis of standard time (i.e. the time given by your watch). The value of the difference between mean solar time and apparent solar time is called the Equation of Time.

Apparent solar time: the time strictly according to the Sun
Mean solar time: the average of the apparent solar time



Question 6: A sundial is "fast", i.e. ahead of standard time, from mid-April to mid-June and from September to winter solstice. A sundial is "slow", i.e. behind standard time, from winter solstice to mid-April, and from mid-June to end of August.

a) How fast is a sundial at the beginning of November? ______________________

b) How slow is a sundial in mid-February? _____________________________

Question 7: Sundial. Design an apparatus to make your sundial read mean solar time instead of apparent solar time. Ask your instructor to check your work. Hint: You might mount your graduated disk onto a larger disk so that it can rotate.

Instructor's initials: ______________

Standard Time: The time on your watch or the time for our entire time zone.
Question 8: When it is noon on your watch in Vancouver, what time is it in

a) London?

b) Calgary?

c) Nelson, BC?

d) When it is noon on a sundial in Vancouver, is it noon on a sundial in Nelson, BC? Explain.

Question 9: ASTR 1101. Calculate the difference in solar time between Vancouver and Nelson. You need to determine the longitude difference between Vancouver and Nelson. Show your calculation.

Question 9: ASTR 3311. Use Starry Night to find the difference in solar time between Vancouver and Nelson. Nelson is at longitude 117º 17' 37.4" W and latitude 49.5ºN. Hint: Find solar noon.

Question 10: There are 24 time zones that are evenly spaced around the world. There are exceptions and variations, but we will try to focus on the general scheme.

a) How wide, in degrees, is a time zone?

b) Find a place in BC for which the standard time corresponds to solar time.

Universal Time
For purposes of navigation and astronomy it is useful to have a single time for the entire Earth. For historical reasons, this "world" time was chosen to be the mean solar time at Greenwich, England (0 degrees longitude), and this time is called the Universal Time (UT). Due to physical processes such as mass motions in the atmosphere, the rate of rotation of the Earth varies from the mean solar time, and so a timescale called Coordinated Universal Time (UTC) has been adopted.

Question 11: The Pacific Time Zone observes standard time by subtracting eight hours from Coordinated Universal Time (UTC) in Greenwich Observatory, England.

a) The clock time in our time zone is based on the mean solar time on a chosen meridian. What is the longitude of that meridian?

b) Find the difference between noon read on your improved sundial (i.e. mean solar time) and noon given by a standard time clock, in winter. Explain.

c) How can you adjust your sundial so that it would read standard time?

d) **Sundial.** Modify your sundial so that one can switch between standard time and mean solar time.

Daylight Saving Time (DST)
In most parts of America and Europe, clocks are set to standard time for only part of the year. In some countries this time changes to daylight saving time (DST), which is 1 hour ahead of standard time.

Question 12: On Dec 1st, you read 4:50 AM on your watch.

a) What is the standard time in Vancouver?

b) What is the standard time in London, UK?

Question 13: On June 25th, you read 7:36 AM on your watch.

a) What is the standard time in Vancouver?

b) What is the standard time in London, UK?

Question 14. Specifically how would you adjust your sundial so that it would read daylight saving time in the summer? Explain exactly. **Sundial.** Modify your sundial so one can switch between daylight saving time and standard time.

Sidereal Time

Question 15: With Starry Night, observe the rising time of a given star.

a) Does it change from day to day? Be precise.

b) Propose a possible explanation for the changes you just described.

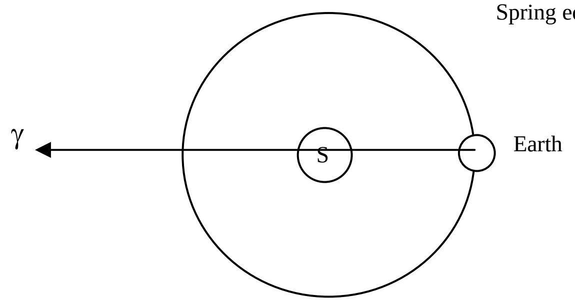
c) Does it take less or more than 24h for the Earth to spin 360° about its rotation axis?

d) How long is a sidereal day?

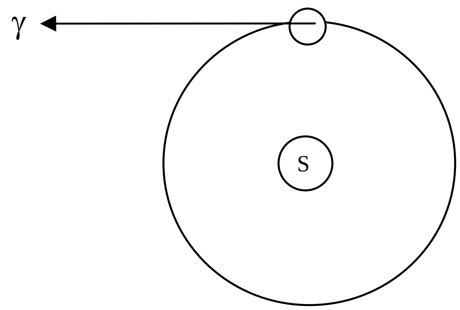
e) **ASTR1101.** What is the time difference between a sidereal clock and a solar clock after 365 days? Show you calculation.

Question 16: Astronomers have set the sidereal clock to be 0 h at noon on Spring Equinox, i.e. when the Sun is at the vernal point. Look at the four diagrams below.

a) Complete the last two diagrams.
b) What is the time difference between the solar and the sidereal clock on the following dates?
c) What are the celestial coordinates of the Sun on these four dates?

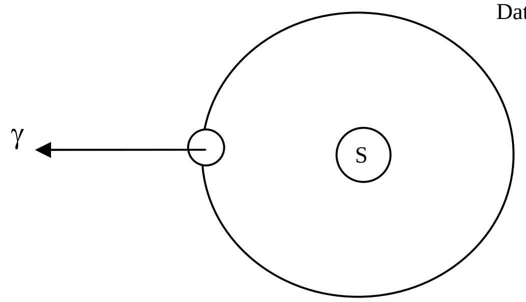


Spring equinox (March)

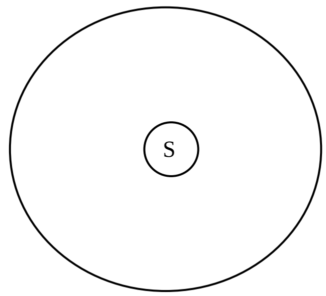


Summer solstice (June)

Date: ________________



Winter solstice (December)



Three Clocks

Astronomical observatories use three clocks.

- The first one is used to tell astronomers when to go for lunch
- The second one is used to coordinate international observing campaigns where several telescopes observe the same object from different latitudes.
- The third one is used to find objects in the sky

Question 17: ASTR 1101.

a) Name the kind of time read on each of the three clocks (apparent solar time, mean solar time, standard time, sidereal time or Universal Time).

b) Which of these clocks could be replaced by your improved sundial during day time on a clear day?

c) Looking at the three clocks above in an astronomical observatory, how would you know the right ascension of the Sun without doing any calculation? (Hint: take a look back at question 16)

d) The sidereal clock displays the local sidereal time of an observatory. You are observing at the Greenwich observatory. What is the right ascension of stars that are crossing the local meridian (i.e. culminating) in relation to the sidereal time?