SESSION FOUR: TIME AND ITS MEASUREMENT

DAYS OF THE WEEK HONOR THE GODS

***StarWatch* 59, October 12, 1997**

The seven days of the week were named after the five naked eye planets, the sun, and the moon. It is obvious where Sunday and Monday came from, and Saturday was named after the Roman god of the harvest, Saturn. But what about the other four days: Tuesday, Wednesday, Thursday, and Friday? These corresponding English words were derived from the Germanic (Norse) gods, Tiw, identified with the Roman god Mars; Woden—Mercury, Thor—Jupiter, and Freyja—Venus. While the year and month had direct relationships to the period of Earth's orbit around the sun, and the duration of the moon's cycle of phases, the week was strictly arbitrary. The Egyptians favored dividing their month into thirds, while the Greeks avoided the week altogether. The Judeo-Christian tradition of a seven day week was officially adopted by the Roman Emperor, Constantine, and solidified under the Council of Nicaea (Iznik in NW Turkey) in AD 325.

DIRECTIONS FROM YOUR WATCH

***StarWatch* 122, December 27, 1998**

You're out hiking and you get lost! You need to find your directions, but foolishly you left your compass at home. You can't find a suitable tree trunk to test the hypothesis that moss always grows on the north facing side. You've got a standard watch (not digital), and the sun is shining. You're safe. You'll be able to find your directions with a fair amount of precision by following this very simple procedure. Orient yourself so that the hour hand of your watch is pointed towards the sun. The midway point between the hour hand and the 12 o'clock position will point south. It is that simple. Flip yourself around so that you are now facing north. Move in a clockwise direction, in quarter circle increments, remembering, that "North never Eats Soggy Waffles." Still facing north, you can also extend your arms to either side of your body and think "WE." Your left arm will be pointing to the west, just like its position in the word "WE," while your right arm will indicate east. You have now delineated the four cardinal points and can begin to get a bearing on your orientation. If you would want to use this same technique to find directions during Daylight Savings Time, use the 1 p.m. position on your watch as the second marker. The midpoint location between the hour hand of your watch which is pointing in the direction of the sun, and the 1 p.m. spot on your watch indicates south. Mrs. Terry Ehrenreich of Catasauqua suggested this topic.

OUR REALITY IS ALWAYS IN THE PAST

***StarWatch* 162, October 3, 1999**

Autumn is probably the best time to view the heavens, especially after our area has been invaded by a dome of dry, unpolluted Canadian air. It is the precursor of the much colder weather which is to follow. Star watching on a crisp fall evening allows us to glimpse our corner of the universe at many different time periods in the past. Our messenger for most of our astronomical knowledge is light, and in its broadest sense, this encompasses the entire array of energies known as the electromagnetic spectrum. Gamma rays, X-rays, ultraviolet radiation, visible light, infrared radiation, microwaves, and radio waves are all part of the "information superhighway" that astronomers use to translate raw data into theory. All of this information travels to us at the incredible speed of 186,000 miles/second. That's per second. It sounds really fast, but in reality the universe is so huge that even this prodigious swiftness is best described as a snail's pace when we talk about seeing the most distant objects. It may take about 13 billion years for the most distant information to reach our telescopes. That's 13 billion **light years** away. Delays are shorter in our solar system. That sunset you witnessed last evening showed old Sol the way it was about eight minutes before it set. If Jupiter is observed in the east at 10 p.m., that really was the way Jupiter looked a little before 9:30 p.m. And Saturn will appear the way it looked about 8:50 p.m. The light radiating from the North Star shows the way it appeared around 1570. By the time we reach out and observe the Andromeda Galaxy, we are now about 2.4 million years into the past. That's when human species was a lot smaller, hairier, and dumber, but nevertheless, upward bound.

JULIAN CALENDAR

***StarWatch* 124, January 10, 1999**

Happy New Year! January 14 marks the beginning of the year according to the Julian calendar. Instituted on January 1, 45 BC, by decree of Julius Caesar, the new calendar resulted from discussions that Caesar had with Egyptian philosophers, including the astronomer, Sosigenes. The whole process of calendar reform began with Caesar's introduction to Cleopatra in 48 BC when she literally had herself "rolled out [from] the 'red carpet'" to greet Caesar. The highlight of the Julian calendar reform was that it finally signaled the end of the Roman lunar calendar which had grown incredibly unwieldy. The Julian calendar took into consideration that the year needed 365-1/4 days to be complete. Three out of every four years were designated as common years containing 365 days, while years divisible by four became leap years of 366 days. The extra day was added to the month of February. It all seemed very neat, but there was still a problem. The Julian year was 11 minutes, 14 seconds longer than the true orbital period of the Earth (Tropical Year). This meant that seasonal markers, such as the first day of winter would occur slightly earlier each year. By 1582 the difference had grown to 10 days, and action was taken under Pope Gregory to straighten out the mess. A rectification of sorts had been made in 325 AD. The result was our present Gregorian calendar. Century years divisible by 400 would now only be considered leap years. Catholic countries adopted the reform immediately, but Protestant states lagged behind. Russia finally acquiesced in 1917. So Jan. 14 (Gregorian) equals Jan. 1 (Julian). So I'll say it again. Happy New Year—Julian style!

EQUATION OF TIME

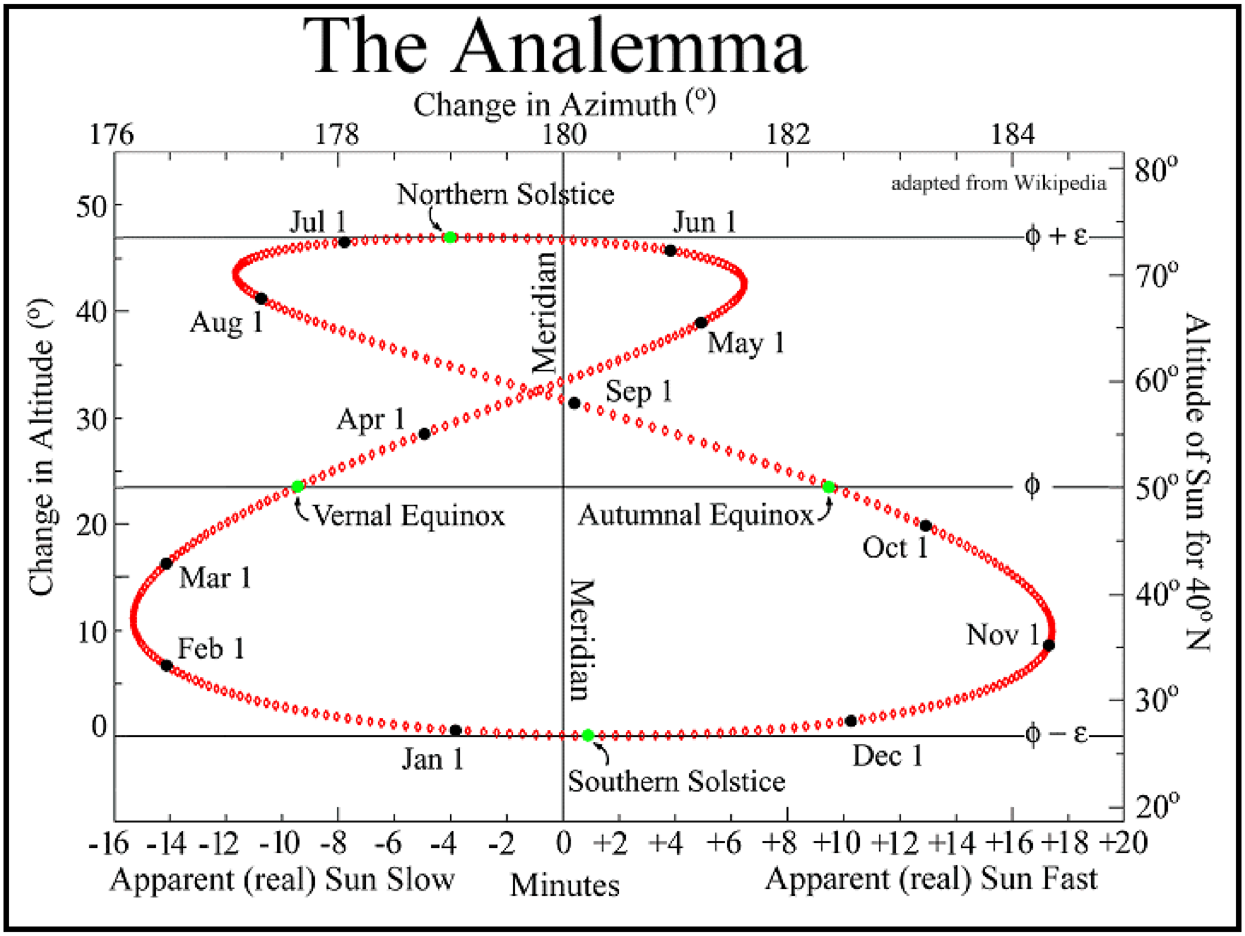
***StarWatch* 334, January 19, 2003**

We have some incredible observers living in the Lehigh Valley, eclectic folks like Len Hvizdos who watch the sun rise and make accurate observations that all of us have witnessed, but few of us have ever contemplated. Len wrote to me and queried that if the shortest day was on December 22 (2002), then why was the sun rising later and later right into early January? His observations were impeccable. The earliest sunset for the Lehigh Valley occurred on December 8, 2002 (4:35 p.m.) and the latest sunrise was on January 5, 2003 (7:22 a.m.). The explanation lies in the fact that we don't really keep time based upon the true position of the sun in the sky. Instead we create the beat of the 24-hour clock with the position of a fictitious sun that moves uniformly along the celestial equator, the projection of the Earth's equator into space. These qualities of the fictitious sun insures that it is always due south at noon, but creates two discrepancies which cause the real sun to stray from the fictitious sun. One is the oval-shaped or elliptical path that the earth takes around the sun during the year. This causes the eastward motion of the real sun to vary against the starry background and either lead or lag behind the fictitious sun. Secondly, the sun's path is tilted by 23.5 degrees to the celestial equator, affecting the real sun's eastward motion as it is shifts to the north or to the south of the celestial equator. This also causes the real sun to lag behind or to lead the fictitious sun. These two independent conditions blend to form what is called the equation of time, which causes the real sun to rise and set slightly out of synch with what our clocks are telling us.

THE ANALEMMA DILEMMA

***StarWatch* 198, June 11, 2000**

Have you ever seen that elongated figure eight on a globe? Usually placed in the Pacific Ocean far away from any land masses, it is called the analemma. If you would observe the sun each day of the year, at noon, and start with the sun due south (June 12), you would see several effects. First, because the Earth's axis is tilted, you would notice the height of the sun changing above the horizon. The sun would appear highest at summer solstice and lowest six months later at winter solstice, but another more subtle motion would also be viewed. As the sun was changing its altitude, it would appear to move to the right and left of the due south position. In other words, as the days passed, your watch would say 12 noon, but the sun might be to the left or to the right of due south. The combination of the change in the height of the sun and its motion to the right or left of south would create the analemma in the sky. Our clocks beat to an average rhythm called mean solar time which has been standardized into time zones and then further modified to daylight saving time during the warmer months. Each day at noon, one p.m. for daylight saving time, an imaginary or fictitious sun is due south by this convention. As the Earth revolves around the sun, it shifts the sun about one degree to the east each day. We correct for this by adding an extra four minutes to the Earth's spin period to create the mean solar day. But the eastward shift of the sun is not uniform. This results from Earth's speed varying due to its elliptical orbit. Another change in the sun's eastward motion results because the sun moves northward and southward with respect to the celestial equator. This is created by Earth's axial tilt. This combination of motions may put the real sun ahead of our clocks by 16 minutes and behind by just over 14 minutes. A detailed analemma can be found on the following page.



HAVE SOME MORE HAPPY JUICE

***StarWatch* 532, October 29, 2006**

Readers of this column know that I have had my share of eye problems, and without some very fine and dedicated physicians, I would probably be writing these articles in Braille. In 1974 during a routine eye exam, my ophthalmologist, Allentown's Dr. Charles Goldsmith, discovered that my retinas were becoming detached from the cup of my eye. When he referred me to Dr. Kenneth Nase in West Reading, I can still remember his exact words. "It's not a screaming emergency!" But it really was! My retinas were detached dangerously close to the fovea or central vision of the eye. Within 10 days I was at Reading Hospital being prepped for the first of two operations in which I had a 30 percent chance of going blind in each eye. As the IV was inserted into my arm, my world became fuzzier, but not my hearing. The discussion among the OR nurses centered about the fact that in several weeks the third shift would have to work nine hours as Eastern Daylight Time fell back to Eastern Standard Time. They were upset because they would only be paid for an eight hour shift, even though the time period between 1-2 a.m. would be repeated twice. "ASTRONOMY," I thought. "I can make a valuable contribution to this conversation." So off I rambled, telling the staff that really their plight wasn't so bad. "Suppose you were working onboard a hospital ship and the vessel crossed the International Date Line sailing in an eastward direction. You'd have to repeat a whole day. So stop complaining," I insisted. "It's only an hour."

Suddenly, I realized that there was a hush in the room. They were actually listening to me in my state of utter euphoria. One of the nurses approached. She smiled and adjusted the IV. “Have some more happy juice,” she said. My world quickly faded into a starry night.

A LEAP OF FAITH

***StarWatch* 601b, February 27, 2008**

It’s time to celebrate because this Friday is leap year day when the month of February has 29 days. The concept of a leap-day is really quite simple. Earth’s Tropical year, the interval of time between two successive solar crossings of the spring equinox, happens every 365.2422 days. Anyone familiar with the calendar knows that we give the Earth only 365 days to complete this task. Every year, our planet lags approximately 1/4-day behind schedule in completing its orbital duties. Four years of under correcting add up to approximately one full day, so a leap-day is added to the calendar to bring the Earth’s orbital position back into general agreement with the sun and the seasons. If the calendar did not contain leap years, then the dates of the year would cycle backwards through the seasons in approximately 1500 years. Christmas would still be celebrated on December 25, but gradually this date would slide into the autumn part of Earth’s orbit and then the summer, while the dates of the solstices and equinoxes would become later by about one day every four years. If leap-days occurred on every year divisible by four (Julian calendar), we would overcorrect the calendar by 0.0078 day each year. In just 128 years the calendar would be off by one day, in this case moving the date of Christmas ahead with respect to the fixed seasons. Since the date of Easter is set by when the sun crosses the spring equinox, far into the future, Christians could be celebrating Christmas and Easter at the same time. This problem was rectified in 1582 by Pope Gregory XIII when century years not divisible by 400 were dropped as leap years. The 365.2422-day Tropical year became nearer to the value of the 365.2425-day Gregorian year. Still, we overcorrect the calendar by 0.0003 day each year. To help correct this error, leap years will not be celebrated in 4,000 and 8,000 AD.

SAVING DAYLIGHT

***StarWatch* 602, March 2, 2008**

Imagine the confusion there would be if every town kept its own local time based upon the motion of the real sun. Not only would travel time need to be taken into consideration, but one would have to add or subtract the change in time based upon whether the travel direction was west (subtract) or east (add). The use of the telegraph and rail transportation caused the US government in 1883 to divide the nation into four time zones with whole hours being added or subtracted when journeying from one zone to the next. Each zone, Eastern, Central, Mountain, and Pacific kept the mean (average) solar time of a standard meridian, 75, 90, 105, and 120 degrees west longitude, respectively. In 1884, an international convention held in Washington D.C. established the same model for the world, with Greenwich, England becoming the official Prime Meridian. For mid-latitude locales, summer sunrises still occurred while most people slept and sunsets coincided with waking hours. William Willett, an English homebuilder in London, conceived and promoted the concept of daylight saving time in 1907 with his publication, entitled "The Waste of Daylight.” Willett conceived advancing the clocks by 20 minutes on successive Sundays in April for a total of 80 minutes, and moving the clocks back by the same amount on successive Sundays in

September. He calculated that by making this adjustment, ₤2.5 million in lighting costs could be saved by the British public. Although his ideas met with Parliamentary champions, it wasn't until May of 1916, a year after Willett's death, that British Summer Time was enacted. Clocks were moved ahead by one hour. Most of the US springs forward to DST the second Sunday in March at 2 a.m., Willett's original time of the day for advancing the clocks.

TRAINING SOLAR TIME

***StarWatch* 765, April 17, 2011**

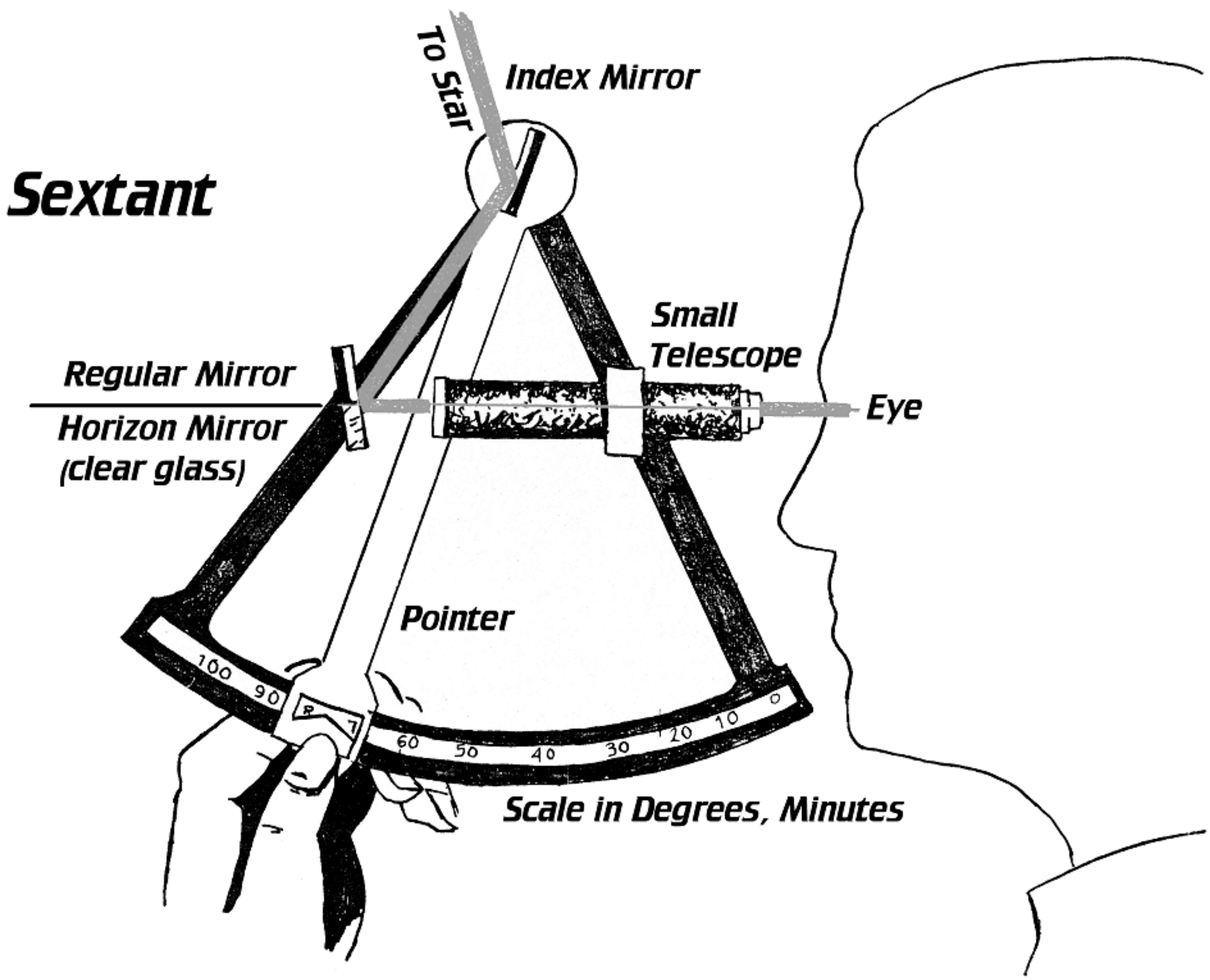
True (apparent) solar time has been used as the basis for time-telling devices since ancient cultures employed it to create calendars for planting and harvesting. The ease of determining the sun's highest position in the sky always led to a precise measurement of solar noon and consequently, apparent solar time. However, it was only accurate for the exact longitude upon which the measurement was based. A few degrees to the east or west would change the local solar time. As railroading gained popularity in the British Isles in the early 1800's, east-west train schedules were forced to reflect local times as well as travel times, and it became almost impossible to merge the two into workable timetables. During this same era, ships were becoming faster, necessitating more accurate international maritime shipping schedules. Mariners began running into similar issues when calculating time based upon the moon's position while on the sea at night. In 1851, Sir George Airy, England's Astronomer Royal, established the Greenwich Meridian, zero degrees longitude, as the standard for measuring time. It became especially important to railroaders who accurately were able to base their timetables from Greenwich Mean Time instead of apparent solar time. By the 1880's, over two-thirds of the world's shippers were using the Greenwich Meridian as their standard. As its popularity grew, it was clear that an official system for time measurement was needed. This was established in October of 1884 when U.S. President Chester A. Arthur convened the International Meridian Conference in Washington to agree upon a time reference. The 41 delegates from 25 nations selected the Greenwich Meridian as the new international Prime Meridian due to its popularity of use. This is the standard that we still use today. This article was written for ***StarWatch*** by Rudy Garbely of Moravian University, Bethlehem, PA. Rudy is an expert on the history of railroading.

Name _________________________________ Date __________________ Moravian University

AN EXERCISE IN BASIC CELESTIAL NAVIGATION

(15 points per plot)

<u>Introduction</u>: The use of an accurate coordinate system for locating the positions of stars and the development of precise chronometers (clocks), that could be used onboard ships, played an essential role in humankind's successful exploration of the world. The ability to stand on the deck of a moving craft on the open seas and accurately determine the ship's position, allowed nations the opportunity to colonize vigorously, establish a more cost-efficient commerce, and eventually reap the benefits of industrialization and technology. The sextant, an instrument used to determine accurately the angle between two objects, was developed by British Admiral John Campbell in 1757. Its predecessors were the Octant, 1731; Edmund Halley's reflecting instrument, 1692; and Joost van Breen's (Dutch) reflecting cross-staff of 1660. Robert Hooke and Isaac Newton also proposed reflecting instruments that could be used for celestial navigation, but were probably never built.



Rationale: Since the Earth is essentially a sphere, each point on its surface represents a unique view of the heavens with respect to the observer's zenith and horizons. As an example, two persons, one in northern Utah and the other in southern Pennsylvania, will essentially see the same stars in the sky over the course of a year. However, if these observers are watching the heavens at exactly the same time, the curvature of the Earth will place the same stars at different altitudes and azimuths in each person's respective sky. In addition, there will be some stars that will have already set in PA, but will still be visible in UT, and other luminaries which have just risen in PA, but have not done so in UT. If we do not know our position on the Earth's surface, we can use the uniqueness of the positions of the stars in the sky for a specific moment in time to work a positional problem backwards and find our unique location on the surface of the Earth. That is the basis for celestial navigation.

You will Need the Following Information and Equipment:

1. **The sidereal or mean solar time must be obtainable at a known position** on the Earth's surface. Greenwich, England, which is the location of the Prime Meridian or 0^o longitude, is the accepted position on the Earth's surface from which longitude is determined. The sidereal time at Greenwich would be represented by the circle of right ascension on the meridian at Greenwich. This data can be provided by a chronometer designed to maintain accurate sidereal time at Greenwich or a regular chronometer which maintains mean solar time (clock time) at Greenwich. The chronometer must be present when the observations are being made because the altitude and azimuth positions of the observed stars are time dependent. Sidereal time can be calculated from mean solar time for Greenwich, England by using tables which show how the sidereal day advances over the mean solar day.
2. **The equatorial coordinates (right ascension and declination) for three widely spaced, bright stars in the sky** must be known. There are 57 official luminaries that have been designated for use in solving celestial navigation problems. These stars can be found in any text that teaches celestial navigation. These stars become visible during Nautical Twilight, when the sun is 6 to 12 degrees below the horizon, and the horizon can also be seen.
3. **A sextant** must be used to measure the altitude of a minimum of three widely separated stars. In this laboratory exercise the altitude of the stars will be given.
4. **The navigator must possess some type of chart or grid system** to plot the sub-stellar positions of the selected stars. The sub-stellar positions represent the latitude and longitude coordinates on the Earth's surface where the specified stars would be found to be at an observer's local zenith when the altitudes were determined from the unknown place.
5. **The navigator should also have a drafting compass** to sweep arcs or circles around the selected stars. These arcs will be equal to the calculated zenith distances, 90^o – the altitude of the selected stars. These arcs are inscribed on the chart from the sub-stellar locations of the plotted stars.

The following **procedure** will be used to find your latitude and longitude position.

1. **Find the sub-stellar positions for the three observed stars:**
    a. **Convert the declinations of the stars directly into latitudes.** The declination at an observer's zenith always equals the latitude position of where that star would be found overhead. The declinations of the stars directly yield their sub-stellar latitude positions on the Earth.
    b. **Find the sub-stellar longitude position of the star**. Note the difference in the sidereal time between Greenwich, England and the three observed stars. Convert these times into angles. Each hour angle of right ascension equals 15^o. Every four minutes of RA is equal to one degree of longitude since the Earth rotates at the rate of one degree every four minutes. Determine whether the stars are east or west of Greenwich to find the best placement for the 0^o longitude line on the chart.
    c. **Plot the sub-stellar location of the stars on an appropriately labeled grid** system of latitude and longitude merged with the equatorial coordinate system.
2. **Convert the altitudes of the stars measured by the sextant into zenith distances** by subtracting them from 90^o.
3. **Utilize your graph paper to its fullest extent** by establishing a scale which places the sub-stellar positions of the stars at their greatest distances from each other. Keep in mind that the scales which are used must be the same for both axes. Graph paper which is 18 inches by 11-1/2 inches and ruled four blocks to the inch can be set up in the following way. Use two blocks for every five degrees equals 20 minutes of arc in right ascension.
4. **With your compass, sweep arcs equal to the zenith distances of the plotted sub-stellar positions** on the grid system. Each arc has its origin at the sub-stellar positions of the stars that were used (graphed) in the exercise.
5. **The intersection positions of the three arcs will be the unique location of the observer** on the Earth who made the measurements with the sextant.
6. **Identify this position accurately** to the nearest half degree as a longitude and latitude location.

<u>RUBRIC</u>: Students will complete one additional navigational exercise for a total of 15 points: The exercise will be completed in class.

This rubric will be used at the discretion of the instructor.	**One half point** will be assigned for each datum in the table provided that the arithmetical work is shown. Remember, units are necessary. Each navigational solution has 12 data entries. Post all information in the graph.	**One point** will be assigned for each star's sub-stellar position when the arithmetical calculations have been correctly shown.	**Six points** total will be assigned to your graphical plot of the location of the observer. Accuracy, correct labeling, neatness, and a title will be considerations in this section.
Point Value	6	3	6

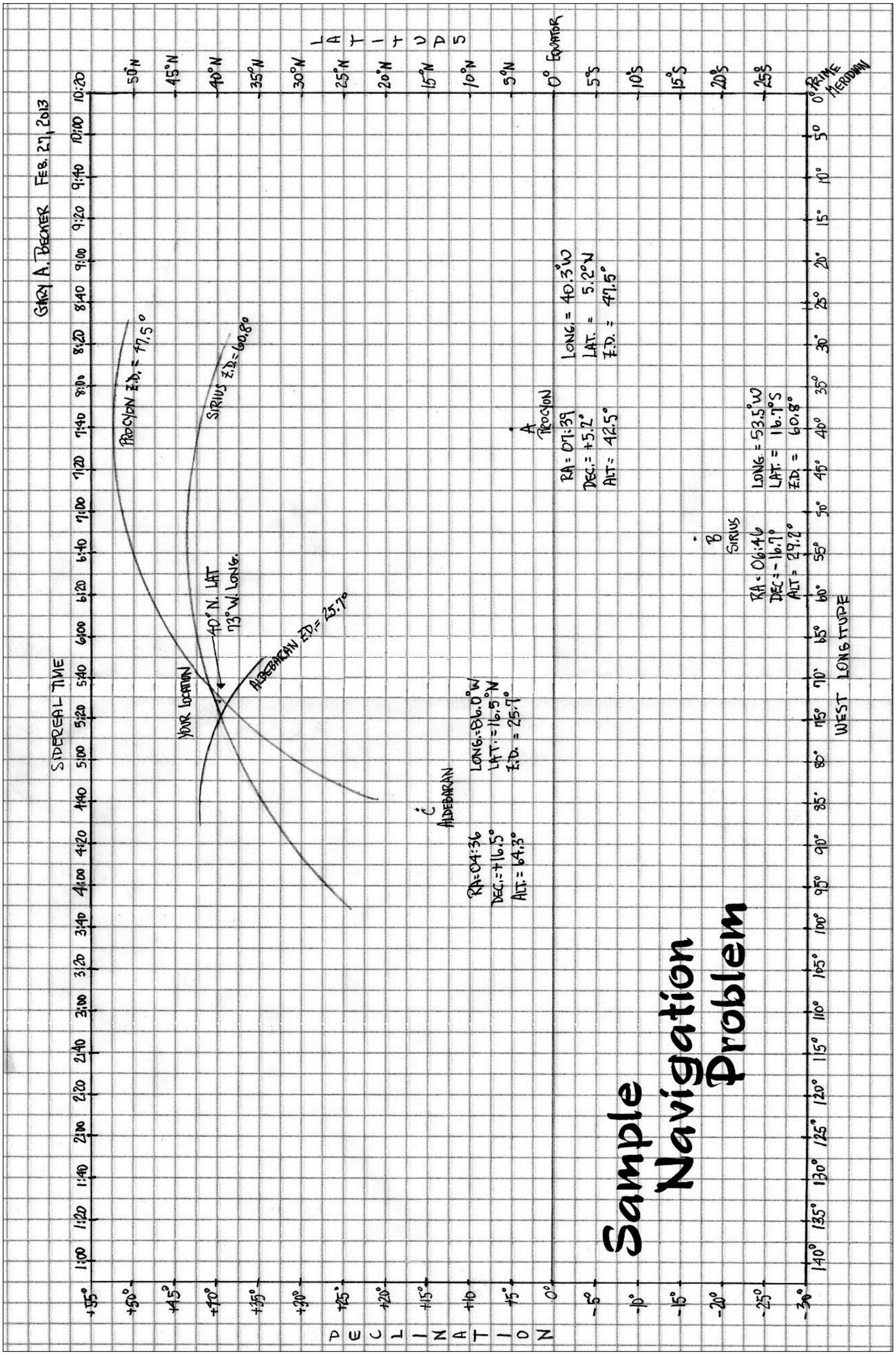
THE MORAVIAN PLOT THICKENS
(Practice Problem)

An astronomy teacher in a small liberal arts university on the East Coast assigns his astronomy class a navigational exercise after a fairly lengthy and animated discussion about coordinate systems which is given during a local planetarium presentation. "Find your position on the Earth. Then take me to your leader," he says. The following data for the stars, including the sidereal time at Greenwich, England, are noted below.

Problem 0	**Sidereal Time at Greenwich**	**Star A** Procyon	**Star B** Sirius	**Star C** Aldebaran
The given stars	**10:20**	**RA: 07:39**	**RA: 06:46**	**RA: 04:36**
are E or W of		**Dec: +05.2º**	**Dec: -16.7º**	**Dec: +16.5º**
Greenwich?		**Alt: 42.5º**	**Alt: 29.2º**	**Alt: 64.3º**
ANSWER	**Longitude**	**40.3º W**	**53.5º W**	**86.0º W**
Long: 73º W	**Latitude**	**5.2º N**	**16.7º S**	**16.5º N**
Lat: 40º N	**Zenith Dist.**	**47.5º**	**60.8º**	**25.7º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.

Star A: **Procyon**	Star B: **Sirius**	Star C: **Aldebaran**
<u>Zenith Distance</u>: 90º – Alt. 90.0º – 42.5º = 47.5º ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: +05.2º Dec. = 05.2º N. Lat. ------------------------------ <u>Long. of Sub-stellar Point</u>: Greenwich 10 hr 20 min - RA Proc. <u>07 hr 39 min</u> 02 hr 41 min $2\text{ hr} \times \frac{15^\circ}{\text{hr}} + 41\text{ min} \times \frac{1^\circ}{4\text{ min}}$ 30.0º + 10.25º 40.3º W. Long.	<u>Zenith Distance</u>: 90º – Alt. 90.0º – 29.2º = 60.8º ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: -16.7º Dec. = 16.7º S. Lat. ------------------------------ <u>Long. of Sub-stellar Point</u>: Greenwich 10 hr 20 min - RA Proc. <u>06 hr 46 min</u> 03 hr 34 min $3\text{ hr} \times \frac{15^\circ}{\text{hr}} + 34\text{ min} \times \frac{1^\circ}{4\text{ min}}$ 45.0º + 8.5º 53.5º W. Long.	<u>Zenith Distance</u>: 90º – Alt. 90.0º – 64.3º = 25.7º ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: +16.5º Dec. = 16.5º N. Lat. ------------------------------ <u>Long. of Sub-stellar Point</u>: Greenwich 10 hr 20 min - RA Proc. <u>04 hr 36 min</u> 05 hr 44 min $5\text{ hr} \times \frac{15^\circ}{\text{hr}} + 44\text{ min} \times \frac{1^\circ}{4\text{ min}}$ 75.0º + 11.0º 86.0º W. Long.



Sample Navigation Problem
GARY A. BECKER FEB. 27, 2013
SIDEREAL TIME
DECLINATION
LATITUDE
WEST LONGITUDE
0° EQUATOR
0° PRIME MERIDIAN
PROCYON Z.D. = 47.5°
SIRIUS Z.D. = 60.8°
ALDEBARAN Z.D. = 25.7°
YOUR LOCATION
40° N. LAT
73° W. LONG.
A PROCYON
RA = 07:39
DEC. = +5.2°
ALT = 42.5°
LONG. = 40.3° W
LAT. = 5.2° N
Z.D. = 47.5°
B SIRIUS
RA = 06:46
DEC. = -16.7°
ALT = 29.2°
LONG. = 53.5° W
LAT. = 16.7° S
Z.D. = 60.8°
C ALDEBARAN
RA = 04:36
DEC. = +16.5°
ALT = 64.3°
LONG. = 86.0° W
LAT. = 16.5° N
Z.D. = 25.7°

NOTES

Problem 1	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**21:00**	**RA: 23:32**	**RA: 01:00**	**RA: 04:36**
are E or W of		**Dec: -18º**	**Dec: +30º**	**Dec: -34º**
Greenwich?		**Alt: 54º**	**Alt: 58º**	**Alt: 34º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.

Star A:	Star B:	Star C:
<u>Zenith Distance</u>: 90º – Alt. ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: ------------------------------ <u>Long. of Sub-stellar Point</u>:	<u>Zenith Distance</u>: 90º – Alt. ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: ------------------------------ <u>Long. of Sub-stellar Point</u>:	<u>Zenith Distance</u>: 90º – Alt. ------------------------------- <u>Latitude of Sub-stellar Point</u> = <u>Declination at Zenith</u>: ------------------------------ <u>Long. of Sub-stellar Point</u>:

Problem 2	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**02:13**	**RA: 23:25**	**RA: 06:29**	**RA: 02:53**
are E or W of		**Dec: +38º**	**Dec: +38º**	**Dec: -28º**
Greenwich?		**Alt: 47º**	**Alt: 13º**	**Alt: 46º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.

Star A:	Star B:	Star C:
Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:

Problem 3	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**21:14**	**RA: 08:02**	**RA: 12:54**	**RA: 11:58**
are E or W of	**IDA Sid. Time Below**	**Dec: -18º**	**Dec: +03º**	**Dec: -52º**
the Inter. Date Line		**Alt: 43º**	**Alt: 30º**	**Alt: 68º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.
Hint: Calculate the sidereal time for 180º longitude and it will be much easier to see whether the stars are east or west of the International Date Line.

Star A:	Star B:	Star C:
Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:

Problem 4	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**07:32**	**RA: 00:20**	**RA: 04:02**	**RA: 02:20**
are E or W of		**Dec: +26º**	**Dec: +42º**	**Dec: -04º**
Greenwich?		**Alt: 45º**	**Alt: 56º**	**Alt: 71º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.

Star A:	Star B:	Star C:
Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:

Problem 5	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**07:17**	**RA: 02:33**	**RA: 02:57**	**RA: 22:17**
are E or W of		**Dec: +16º**	**Dec: -28º**	**Dec: -40º**
Greenwich?		**Alt: 46.5º**	**Alt: 59º**	**Alt: 45º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.

Star A:	Star B:	Star C:
Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------- Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:

Problem 6	**Sidereal Time at Greenwich**	**Star A**	**Star B**	**Star C**
The given stars	**00:52**	**RA: 10:07**	**RA: 18:36**	**RA: 16:30**
are E or W of	**IDA Sid. Time Below**	**Dec: +12º**	**Dec: +39º**	**Dec: -26º**
the Inter. Date Line		**Alt: 26º**	**Alt: 20º**	**Alt: 44.5º**
ANSWER	**Longitude**	**º**	**º**	**º**
Long: º	**Latitude**	**º**	**º**	**º**
Lat: º	**Zenith Dist.**	**º**	**º**	**º**

Show all work below. Do not forget to submit your labeled, scaled, and titled graph.
Hint: Calculate the sidereal time for 180º longitude and it will be much easier to see whether the stars are east or west of the International Date Line.

Star A:	Star B:	Star C:
Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. of Sub-stellar Point:	Zenith Distance: 90º – Alt. ------------------------------ Latitude of Sub-stellar Point = Declination at Zenith: ------------------------------ Long. Of Sub-stellar Point:

TIME AND ITS MEASUREMENT VOCABULARY LIST

1. **Altitude:** The angular measurement of an object from the horizon along the vertical circle which contains the object to the object in question.
2. **Analemma:** The graphical representation of the equation of time. It looks like a figure eight. Its vertical representation depicts the change in the sun's declination during the year while horizontally it shows how the apparent sun either lags behind or runs ahead of the mean sun.
3. **Apparent Solar Time:** The time based upon the true position of the sun in the sky.
4. **Astronomical Twilight:** The time period before sunrise or after sunset when the sun is between six and 12 degrees below the horizon. More precisely, the zenith distance of the sun must be between 102^o and 108^o.
5. **Azimuth:** The angular measurement of an object made along the horizon, starting at north and moving eastward to the vertical circle which contains the object.
6. **Celestial Equator:** The projection of the terrestrial equator onto the celestial sphere. It divides the north celestial hemisphere from the south celestial hemisphere.
7. **Celestial Sphere:** The dome of the sky which lies above an observer's head.
8. **Civil Time:** Mean solar time. The time that is being kept by ordinary clocks.
9. **Civil Twilight:** The period from sunset to when the center of the sun is six degrees below the horizon. The interval before sunrise when the center of the sun is six degrees or less from the horizon. More precisely, it is the zenith distance of sun when it is between $90^o\,50'$ and 96^o.
10. **Civil Year:** The year calculated for ordinary purposes. It either contains 365 or 366 days.
11. **Day:** A period of 24-hours or the time it takes for the mean sun traveling uniformly along the celestial equator to transit the meridian twice. It is equal to 86,400 seconds.
12. **Daylight Saving Time:** A convention legislated by governments to bring mean solar time into better agreement with human activity. The standard meridian is moved one hour to the east. Time jumps ahead (gets later) by one hour when standard time changes to Daylight Saving Time. It is incorporated during the majority of the year centered on the summer months. There is no "s" at the end of "Saving."
13. **Declination:** The angular measurement of an object north or south of the celestial equator, along the vertical circle that contains the object to the object.
14. **Eastward Motion (with respect to time):** Time becomes later…
15. **Ecliptic:** The plane of the Earth's orbit around the sun projected into space. The sun is always located on the ecliptic.
16. **Equation of Time:** The variation in the transit times of the apparent sun in comparison to the mean sun. These differences result from the Earth's change in orbital speed due to its elliptical (oval shaped) path around the sun and the northerly and southerly motion of the sun that results from Earth's axial tilt. The graphical representation of the equation of time is called the analemma.
17. **Equatorial Coordinate System:** The system of right ascension and declination which is a projection of longitude and latitude into space. The vernal equinox represents the origin of the system.

18. **<u>Great Circle</u>:** The largest circle possible on any sphere. The center of the circle must be positioned at the center of the sphere. The meridian, circles of right ascension, and all vertical circles are great circles.
19. **<u>Gregorian Calendar</u>:** Inaugurated by Pope Gregory XIII in 1582, this calendar brought into better correction the revolution period of Earth with the year. All common years divisible by four continued to be leap years, but century years had to be dividable by 400. This brought the tropical year into closer agreement with the civil year.
20. **<u>Greenwich Mean Time</u>:** (GMT) The mean solar time calculated for the Prime Meridian located at Greenwich, England.
21. **<u>Hour Angle</u>:** The angle measured westward from the meridian along the celestial equator to the hour circle which contains the sun.
22. **<u>Hour Circle</u>:** Any great circle in the equatorial coordinate system which is perpendicular to the celestial equator.
23. **<u>International Date Line</u>:** An arbitrary location (averaging about 180 degrees longitude) where the eastward or westward motions of an observer are corrected by either adding a day (westward motion) or subtracting a day (eastward motion).
24. **<u>Julian Calendar</u>:** Rome's first solar civil calendar, devised by Cleopatra's astronomer Sosigenes, and inaugurated on January 1, 45 BC by Julius Caesar. All years dividable by four were leap years.
25. **<u>Julian Date</u>:** The number of days that have elapsed since noon GMT on January 1, 4713 BC. It is used to establish a reference system of time which can be used worldwide to standardize observations.
26. **<u>Latitude</u>:** The angle measured from the center of the Earth northward or southward from the equator along the vertical circle that contains the object, to the object.
27. **<u>Leap Year</u>:** The method of correcting the calendar to bring it into closer agreement with the tropical year which is about one quarter day less than the orbital period of the Earth. Years divisible by four and century years divisible by 400 are currently leap years under the rules of the Gregorian calendar.
28. **<u>Leap Year Day</u>:** The day, February 29, that is designated as the day to bring into synchronization the tropical year with the Earth's revolution period.
29. **<u>Longitude</u>:** The angular distance measured from the Earth's center along the equator westward or eastward from the Prime Meridian to the vertical circle containing the object.
30. **<u>Mean Solar Time</u>:** The time based upon the uniform motion of a fictitious sun along the celestial equator. It is the same as civil time.
31. **<u>Meridian</u>:** A great circle which lies on the celestial sphere and intersects the north and south points along the horizon, the north and south celestial poles, and the observer's zenith.
32. **<u>Nautical Twilight</u>:** The time period either before sunrise or after sunset when the sun is between six and 12 degrees below the horizon. During nautical twilight the 57 stars necessary for celestial navigation are visible. The horizon is also still visible making this the ideal time to observe the altitude of these navigational stars with a sextant. During nautical twilight the zenith distance of the sun is between 96° and 102°.
33. **<u>North/South Celestial Pole</u>:** The point of intersection of the Earth's axis and the celestial sphere. In the northern hemisphere that point is less than one degree from Polaris.

34. **Polaris:** The Pole Star or the North Star… In the Northern Hemisphere, it is the star closest to the North Celestial Pole.
35. **Prime Meridian:** The origin of longitude arbitrarily created by human convention. It passes through the Royal Observatory located in Greenwich, England.
36. **Right Ascension:** The angle measured as a time coordinate eastward from the vernal equinox along the celestial equator to the hour circle which contains the object.
37. **Sextant:** A navigational instrument which allows the user to find precisely the altitude of a star in the sky.
38. **Shoot a Star:** A term used when a navigator, using a sextant, finds the altitude (takes a fix) of a star in the heavens.
39. **Sidereal Day:** The time it takes the Earth to complete one rotation on its axis—23 hours, 56 minutes, 4 seconds.
40. **Sidereal Time:** The circle of right ascension crossing an observer's local meridian.
41. **Sidereal Year:** The period of time necessary for the Earth to complete one orbit around the sun with respect to a distant star. Its duration is 365.26 days.
42. **Standard Time:** The mean solar time normalized for a specific circle of longitude.
43. **Transit:** To cross a reference position. As an example, the mean sun transits the meridian at noon each day.
44. **Tropical Year:** The time period between two passages of the center of the sun through the vernal equinox.
45. **Universal Time:** Greenwich Mean Time… It represents mean solar time on the Prime Meridian, 0^{o} longitude.
46. **Vernal Equinox:** The position in the sky where the sun moving along the ecliptic intersects the celestial equator traveling in a northward direction. It represents the first moment of spring.
47. **Vertical Circle:** A great circle which passes through an observer's zenith and is also perpendicular to the horizon.
48. **Westward Motion (with respect to time):** Time becomes earlier…
49. **Year:** It is also called the civil year. It is the time period of 365 or 366 days upon which our calendar is based.

NOTES

CAN YOU ANSWER THE FOLLOWING QUESTIONS/STATEMENTS ABOUT TIME AND ITS MEASUREMENTS?

INTRODUCTION

1. _______________ is a human made concept which allows us to place events accurately in some sequential order.

2. Time intervals have their root in astronomical observations. For example, the rotation of the Earth about its axis could loosely define the _______________. The year is based upon one _______________ of the Earth around the sun, while the moon's phase period gives logical understanding to the origin of the _______________. The sun, the moon, and the five planets which were observed during antiquity, led to the establishment of the _______________.

APPARENT SOLAR TIME

3. The _______________ is a great circle which intersects the horizon at the observer's south and north points, while also intersecting the zenith. It must also intersect the north and south celestial poles, where the Earth's axis intersects the ____________________.

4. The concept of a 24-hour day dates back to the ancient Egyptians. They divided their sky into 24 nonequal and changing parts. The 24-hour clock in use today depends upon the position of the _______________ in the sky with respect to an observer's local meridian.

5. Using a (nighttime) star to facilitate time-keeping would be highly impractical. The sun and the reference star would soon be out of synchronization. The sun shifts its position eastward among the stars by about one degree per day as the result of Earth's _______________. A mean (average) solar day is equal to _______________ of clock time, but one rotation of the Earth takes ____________________ of clock time. Time based on the successive transits of a star across the meridian would soon find the star and the sun out of phase. In just six months, day and night would be completely reversed causing continual disruptions in human activity. Time based upon the successive transits of a star on the meridian is called _______________ time. This is, however, not a strict definition.

6. To regulate our daily activities we are interested in having the _______________ return to the same position in the sky in a uniform time interval. Therefore, we must add approximately _______________ to the sidereal day to allow the Earth's rotation to move the sun to its crossing position on the meridian.

7. The projection of the terrestrial equator onto the celestial sphere creates the ____________________.

8. The angle measured westward from the meridian along the celestial equator to the hour circle which contains the sun is referred to as the sun's ____________________. Since this angle is measured as a function of time, it is stated in units of _______________, _______________, and _______________.

9. When the sun is on the meridian, its hour angle is _______________. As the Earth rotates, the sun is carried towards the west. It eventually sets and continues its path beneath the horizon to reappear in the east and make its climb back to the meridian. During this interval, the sun's hour angle increases from zero to _______________, similar to military time.

10. Apparent Solar Time = Hour Angle of the Sun + 12 hours if the hour angle of the sun is between _______________ and _______________ hours.

11. If the hour angle of the sun is greater than 12, it will be necessary to subtract _______________ hours from the total to obtain the correct time.

12. The hour angle of the sun is 3 hours, 15 minutes. Based upon a military system of time-keeping (a 24-hour clock) the apparent solar time is _______________. With regards to a regular 12-hour clock the time is _______________. Don't forget the a.m. (ante meridiem) which means "before the meridian" or the p.m. (post meridian) which means "after the meridian" if military time is not being used.

13. The hour angle of the sun is 21 hour, 41 minutes. Stated as military time the apparent solar time is _______________. On a 12 hour clock this would correspond to _______________.

14. The apparent solar time is 19 hours, 16 minutes. The hour angle of the sun is _______________.

15. The apparent solar time is 9 hours, 12 minutes. The hour angle of the sun is _______________.

MEAN SOLAR TIME

16. The problem with the apparent solar day is that the time intervals of successive local meridian transits of the sun are never precisely the same. These changing intervals result from a variation in the Earth's orbital speed as it revolves around the sun in an elliptical path. In order to create uniformity in our time-keeping system, the apparent solar day is averaged to create the _______________ solar day.

17. The change in the length of the apparent solar day arises because the eastward movement of the sun is not uniform. This motion is a result of changes in the velocity of Earth as it ________________ around the sun. The Earth's orbital shape is an ________________. This factor causes Earth to move faster when closer to the sun and slower when farther away. When the Earth has a higher orbital velocity, the sun's eastward motion is GREATER/SLOWER (circle one).

18. A secondary reason why the eastward motion of the sun varies is due to its northerly and southerly change in ________________.

19. The sun's greatest daily eastward motion should occur when the Earth is closest to the sun, giving the Earth its highest orbital velocity. Another helpful effect would occur when the sun has a minimal daily change in declination and its entire component of motion along the ecliptic would be directed towards the east. This does occur during the season of ________________.

20. Even though apparent solar time is vastly superior to sidereal time in monitoring our daily activities, it is still not uniform enough. Astronomers have therefore invented a fictitious sun called the ________________ sun. It is merely an imaginary point in the sky which moves uniformly along the celestial equator so that it will make successive transits of the meridian in precisely ________________________________.

21. Just like apparent solar time, mean solar time utilizes a 24-hour clock system equal to the _h__________a___________ of the mean sun + or - 12 hours.

EQUATION OF TIME

22. The difference in time measured by the apparent sun and the mean sun is referred as the ___________________________. More precisely, it is apparent solar time - mean solar time. Think of the mean sun uniformly transiting the meridian. The apparent sun will sometimes transit ahead of the mean sun, and at other times of the year, it will transit behind the mean sun.

23. If the apparent sun leads the mean sun, the equation of time is POSITIVE/NEGATIVE (circle one). If the apparent sun lags behind the mean sun, the equation of time is POSITIVE/NEGATIVE (circle one). Below are found the approximate equations of time to the nearest minute for the first day of each month

Jan 1: - 4	Apr 1: - 5	Jul 1: - 8	Oct 1: +12
Feb 1: -14	May 1: + 5	Aug 1: - 5	Nov 1: +17
Mar 1: -14	Jun 1: + 4	Sep 1: + 0	Dec 1: +10

On Jan 1 the apparent sun transits the meridian about four minutes after the mean sun. When the real sun (apparent) sun runs behind the mean sun (civil time) the equation of time is negative. When the real sun is ahead of the mean sun, the equation of time is positive.

24. A very famous method of graphically depicting the equation of time is through a "figure 8" shaped diagram called an _______________.

LOCAL TIME

25. Until this point in our discussion, apparent solar time and mean solar time have been determined from the observer's meridian. There has been no attempt to standardize these times into zones. They are strictly local in nature, dependent upon one's _______________ position on Earth.

26. Therefore if an individual moved west (causing the sun to move toward the east), time would get EARLIER/LATER (circle one). Just the opposite would be true if you moved eastward.

27. The sun, on average, returns to the same meridian in a 24-hour period, completing a full circle **(360 degrees)** around the sky. Since there are **1440 minutes** in a day, each degree of the sun's motion is equal to _______________ minutes of time. Another way of stating this concept is to say that the Earth rotates ______________ degree every four minutes. That is approximately equal to the angle subtended (extend from one side to the other) by two full moons side-by-side.

28. An astronomer notes the local time at his position of 104 degrees west longitude as 15:40 (3:40 p.m.). In Allentown, PA, located at 75 degrees west longitude, the local time would be _______________. Allentown is 29 degrees to the WEST/EAST (circle one) of 104 degrees west. When you go east, local time gets _______________. When you go west, local time gets _______________. For each longitude degree traveled east or west, local time changes by _______________.

29. Greenwich, England is a reference position for calculating a worldwide time system based upon the local mean time at one meridian. Greenwich corresponds to a longitude position of _______________. The time at Greenwich can be referred to as Greenwich Mean Time or **U______T____**.

30. Local mean time = UT + longitude (east of Greenwich)
    UT - longitude (west of Greenwich)

    It is 00:12 UT (in Greenwich). The local time in Pittsburgh, Pennsylvania situated at 80 degrees west longitude would be _______________. If it were January 1st in Greenwich, the date in Pittsburgh would be _______________.

31. It is 00:12 (in Greenwich). The local time in Cairo, Egypt located at 31 degrees east longitude would be ______________. If it were January 1st in Greenwich, the date in Cairo would be _______________.

32. The difference in local time between any two places on the Earth is simply the difference in _______________ between them.

TIME ZONES

33. In the latter part of nineteenth century as travel by train became more common, confusion in scheduling occurred because it was necessary to consider the differences in local times resulting from changes in longitude between rail stops as well as the time it would take to cover the distances between towns. The solution was the creation of time ________________ in 1883 where all locations would adhere to the ______________________ time found at a particular standard meridian.

34. Although the boundaries of these time zones are legislated, their centers correspond to whole hour angles east and west of Greenwich. To the east of Greenwich, there are ________________ standard time zones, but to the west, there are only ________________. Since Greenwich is a standard time zone, this makes 24 in total.

35. In North America there are six standard time zones. From east to west they are named ________________, ________________, ________________, ________________, ________________ (includes nearly all of this state), and ________________, Universal Time -10 hours represents the standard time in ________________.

36. Going east or west eventually brings about the addition or subtraction of a day at the location known as the ________________________________. This line of demarcation at approximately 180 degrees longitude "jogs" back and forth so it does not bisect any land mass.

37. Crossing the IDL in a westward direction will cause the date to flip AHEAD/BEHIND (circle one) by one day.

38. You are on board a ship outbound from Singapore for Honolulu, Hawaii and have just brought in the New Year. The place is a mess with confetti, pompoms, streamers, broken balloons, and the like. The captain announces over the loudspeaker that the ship has just crossed the International Date Line. The passengers cheer, but you notice that the waiters look disappointed. Why?
____
____

39. Many governments have legislated the addition of an extra hour to the standard time of a zone during the summer months. This is called _____________________ time. This procedure moves the time zone one hour to the EAST/WEST (circle one). Therefore, instead of the sun rising at 4:30 a.m. and setting at 7:30 p.m., like it would in the Lehigh Valley if we were on Eastern Standard Time, the sun rises at ________________ and sets at ________________. The amount of daylight remains the ________________.

40. Daylight time brings human activities more in line with the time when the ________________ is visible.

41. Although the period of Earth's rotation may seem to be uniform, when compared to the extreme accuracy of atomic clocks, it is found that Earth's rotational period is INCREASING/DECREASING (circle one) by about 1/1000th second per century. Coronal mass ejections and earthquakes can also increase or decrease the rotational speed of the Earth.

42. This change in Earth's rotation results from friction caused by the tidal bulge created by the moon's (differential) gravity acting on the Earth. Because of Earth's rotation, the tidal bulge is formed slightly AHEAD/IN BACK (circle one) of the moon's position. The effect is to _______________ the moon, causing it to spiral slowly away from Earth. Since the angular momentum (total amount of spin) of the Earth-moon system must be conserved, the Earth's rotational period must become LONGER/SHORTER (circle one) as time advances.

43. Since it is still the Earth's rotation with which we are most concerned, astronomers occasionally adjust their atomic clocks by incrementing an addition _______________ second to bring their time into better synchronization with the Earth's rotation period.

SIDEREAL TIME

44. Solar time is based upon the repeated returns of the sun to one's local _______________. This does not correspond to the rotation period of the Earth which is ______ hrs. _______ minutes in length.

45. During the period of one Earth rotation, the Earth moves about one degree in a counterclockwise direction around the sun. This shifts the sun about one degree to the east____________________ with respect to the sun's direction of motion among the stars.

46. Therefore in order to return the sun back to the meridian, the Earth must make one complete rotation plus continue through one degree of additional rotation to return the sun back to the meridian. This extra time takes approximately _______________.

47. However for a star, exactly one Earth rotation will return it to exactly the same location in the sky. This is important for astronomical observations, for it gives astronomers an easy method for locating objects in the sky if they allow their observatory clocks to keep _______________ time rather than solar time.

48. Just like the 24 hours of clock time we use during the day, astronomers divide the rotation period of the Earth into 24 hours of _______________ time. Each corresponding unit (hour, minute, second) is SHORTER/LONGER (circle one) than its corresponding period of clock time.

49. Solar is to sun as sidereal is to _______________! A star transiting (crossing) the meridian will be returned to the meridian in a period of one Earth rotation or one _______________ day. In clock time this interval equals ____________________.

50. Sidereal time has a direct relationship with one of the components of the equatorial coordinate system called ____________________.

51. The origin of the equatorial coordinate system occurs at the ____________________ which is located at the intersection of the ecliptic, where the sun is moving north, and celestial equator. This is the position of the sun at the first moment of spring.

52. The hour angle that the vernal equinox is west of an observer's local meridian represents the _______________ time at that observer's position.

53. The hour angle of the vernal equinox equals the circle of ____________________ crossing an observer's local meridian. Knowing the sidereal time occurring for a particular clock time gives the ____________________ transiting the meridian and allows the observer to know what is visible in the sky at that location.

THE JULIAN AND GREGORIAN CALENDARS

54. The natural units of the calendar are the day, based upon the _______________ of the Earth; the month, based upon the _______________ cycle of the moon; and the year, based upon the _______________ of the Earth.

55. The period of revolution of the Earth with respect to the vernal equinox is called the _______________ year. It is equal to 365.242199 days in length. It is the tropical year we use for calendrical purposes.

56. Almost all calendars were originally based upon the _______________ cycle of the moon. This is understandable because the moon is a bright object and easy to observe, while its phases occur in a much SHORTER/LONGER (circle one) period of time than the interval of a year.

57. All civilizations knew that it was the ______________ which was important to the growing of crops. The solution, to correct for the fact that the phase period of the moon did not divide integrally into the tropical year, was to add extra months to bring the lunar calendar into phase with the tropical year. This process is known as _______________.

58. The roots of our present-day calendar go back to the _______________ Republic which originally used a lunar scheme. The year was composed of 12 months totaling 355 days. Every two to four years an extra month had to be _______________ to bring the calendar back into alignment with the sun. This was always done following the month of February.

59. Because of political mismanagement of the lunar calendar by the Roman priests, ____________________ (a person's name) adopted the concepts of a new solar calendar in 45 BC. It was composed of 12 months and contained 365 days.

60. This calendar, named the ______________ calendar, went into effect on January 1st, 45 BC

61. It was well known by Sosigenes, Cleopatra's Egyptian astronomer that the tropical year actually contained about _______________ days. Each year the Earth was given one quarter day less time than it needed to complete its revolution around the sun. The result was that after four years the Earth lagged one full day behind the seasons. The problem was solved by intercalating _______________ day every four years at the end of February to bring the Earth in step with the sun. All years divisible by four were designated as ____________________.

62. The Julian year had 365.250000 days, while the tropical year was 11 minutes shorter with 365.242199 days. In 325 AD the Council of Nicaea fixed the dates when Easter could occur in relation to the sun's crossing of the vernal equinox. Since the repetition of Easter was a function of the tropical year, the date which the sun crossed the vernal equinox, according to the Julian calendar, would gradually over the centuries become EARLIER/LATER (circle one).

63. Eventually the Julian dates for Easter would begin interfering with the fixed date of another important Christian holiday, _______________. Pope _______________ XIII instituted additional calendar reforms in 1582 by dropping 10 days from the year to restore the date of the sun's crossing of the vernal equinox to about March 21. October 4, 1582 was followed by October 15th. In the matter of leap years, all years divisible by four were still considered leap years, but only century years divisible by _______________ were designated as such. This new calendar was called the _______________ calendar and had 365.242500 days as compared to the tropical year of 365.242199 days. The calendar was now accurate to one day in 3300 years.

ANSWERS TO SESSION FOUR QUESTIONS

INTRODUCTION

1. time
2. day, revolution, month, week

APPARENT SOLAR TIME

3. meridian, celestial sphere
4. sun
5. revolution; 24 hours; 23 hours, 56 minutes; sidereal
6. sun, four minutes
7. celestial equator
8. hour angle, hours, minutes, seconds
9. zero, 24
10. zero, 12
11. 24
12. 15:15, 3:15 p.m.
13. 09:41, 9:41 a.m.
14. 7 hours, 16 minutes
15. 21 hours, 12 minutes

MEAN SOLAR TIME

16. mean
17. revolves, elliptical (oval), GREATER
18. declination
19. winter
20. mean, equal time intervals
21. hour angle

EQUATION OF TIME

22. equation of time
23. POSITIVE, NEGATIVE
24. analemma

LOCAL TIME

25. longitude (unique)
26. EARLIER
27. four, one
28. 17:36 (5:36 p.m.), WEST, later, earlier, four
29. zero degree
30. 18:52 (6:52 p.m.), December 31st
31. 02:16 (2:16 a.m.), January 1st
32. longitude

TIME ZONES

33. zones, mean local (same)
34. 12, 11
35. Atlantic, Eastern, Central, Mountain, Pacific, Alaska, Hawaii; Hawaii
36. International Date Line
37. AHEAD
38. The servers will have to repeat the whole New Year's Eve party again tonight! It is now only the morning of December 31st.
39. daylight saving, EAST, 5:30 a.m., 8:30 p.m., same
40. sun
41. INCREASING
42. AHEAD, accelerate, LONGER
43. leap

SIDEREAL TIME

44. meridian; 23 hours, 56 minutes
45. east, EASTWARD
46. four minutes
47. sidereal
48. sidereal, SHORTER
49. stars; sidereal; 23 hours, 56 minutes
50. right ascension
51. vernal equinox
52. sidereal
53. right ascension, right ascension

THE JULIAN AND GREGORIAN CALENDARS

54. rotation, phase, revolution
55. tropical
56. phase, SHORTER
57. sun (year), intercalation
58. Roman, intercalated
59. Julius Caesar
60. Julian
61. 365¼, one, leap years
62. EARLIER
63. Christmas, Gregory, 400, Gregorian

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