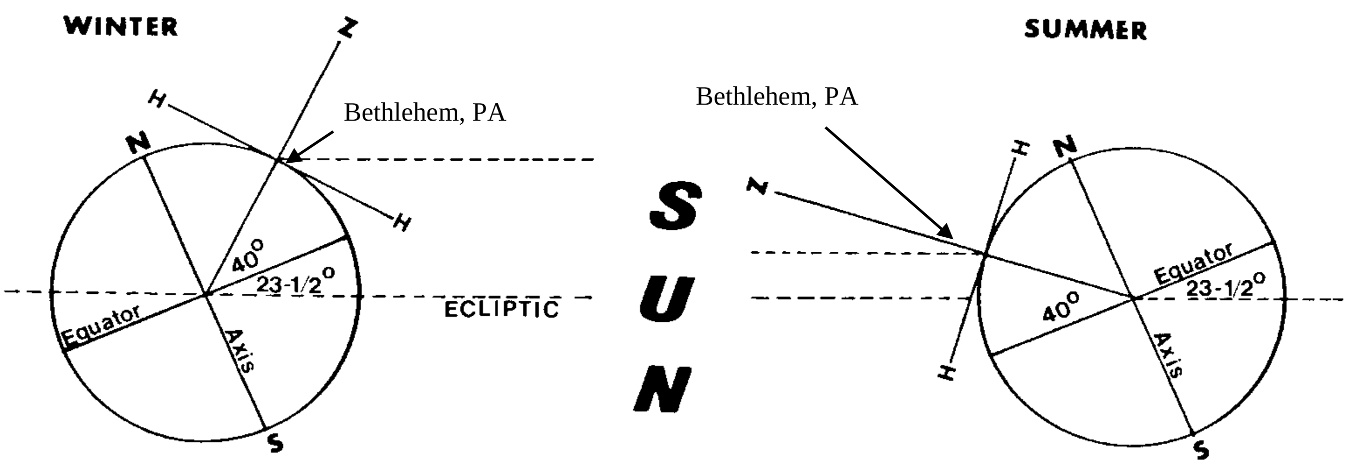
UNDERSTANDING THE SEASONS

The fact that the weather is warmer in the northern hemisphere in summer and colder in winter is **<u>NOT</u>** because the sun is nearer to us in summer and farther from us in winter. In actuality, the summer sun is three million miles farther from the Earth than its winter distance. The two factors which produce the seasonal effects are (1) the duration of sunlit hours experienced during each season and (2) how directly the sun's rays strike the Earth's surface. These two factors are in essence due the 23.5degree inclination of the Earth's axis from the perpendicular to the ecliptic and the axis pointing in the same direction.



In summer, the northern half of the Earth's axis is tipped toward the sun. Not only is the duration of daylight longer at any place in the northern hemisphere, but the sun transits the meridian at a higher altitude, so that its rays are more nearly vertical with the ground, and therefore, more concentrated. In winter, the northern hemisphere of the Earth is tilted away from the sun. The duration of daylight is shorter, and the sun transits the meridian at a lower altitude. The sun's rays strike the Earth at a shallower angle and thus impart to the surface of Earth less energy per unit area.

As a result of the Earth's revolution around the sun, the sun appears to move eastward along the ecliptic approximately one degree per day. The 23.5 degree tilt of the Earth's equator to the plane of its orbit causes this eastward motion to simultaneously have a northward or a southward component depending upon the season. This causes the sun to be north of the celestial equator for half of the year and south of the celestial equator for the other half. The sun's declination changes by 47°. This yearly shift is twice the inclination of the celestial equator to the ecliptic. The variation in declination causes the sun's daily path across the sky to change. This creates a variation in the length of time that the sun is above the horizon.

<u>Purpose</u>: The purpose of this laboratory exercise will be to investigate the seasons by observing the altitude changes of the sun at different times of the year and at different latitudes and to compare the changes in the duration of sunshine (insolation) at these latitudes.

Procedure: A planetarium or planetarium computer program will be used to demonstrate the seasonal effects for a variety of different latitudes, stressing 40 degrees north. At this latitude the planetarium will be set for noon on March 21 and the projector or program advanced in increments of three months until a year has passed. Note the change of the sun in right ascension and declination, as well as the altitude of meridian transit (noon) and the azimuth of sunrise and sunset during this period.

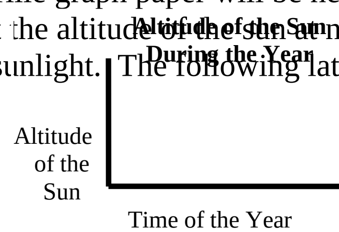
Sun's Location from Bethlehem, PA, 40° North Latitude

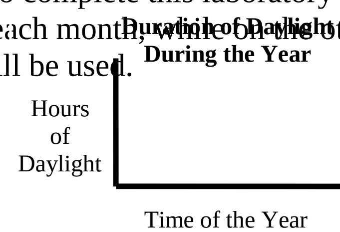
Date	Sunrise Azimuth	Altitude of the sun at Noon	Relative Flux Sine of Alt.	Sunset Azimuth	Duration of Daylight	RA of the Sun	Dec. of the Sun
March 21							
June 21							
September 21							
December 21							

PLOT THE DATA FOR 40 DEGREES NORTH LATITUDE FIRST. If the planetarium or a computer program is not used to establish the data in the above table, use the information found on the data pages following the relative flux information. The RA and Dec. of the sun will not be given in the tables. Use the information associated with 40 degrees N latitude to estimate the data of the other highlighted latitudes on the chart.

Two pieces of quadrille graph paper will be necessary to complete this laboratory exercise. On one sheet plot the altitude of the sun at noon for each month, while on the other graph, plot the duration of sunlight. The following latitudes will be used.

66 ½° N
40° N
23 ½° N
0°
23 ½° S





Use the tables of data found in the back of this exercise to construct the graph. On the one graph, altitude (in degrees) should be marked off along the vertical (Y axis), with three spaces per 10°. In the second graph, the Y axis will be representative of the times of sunrise and sunset. Each space will count for one hour of time. Start with midnight (0 hours) at the vertex, and proceed to 24 hours (midnight) in one hour increments. Along the X axes for both graphs, plot the times of the year, starting with March 21 and repeating the same date at the end of the plot. Each month will be represented by three spaces on the graph paper.

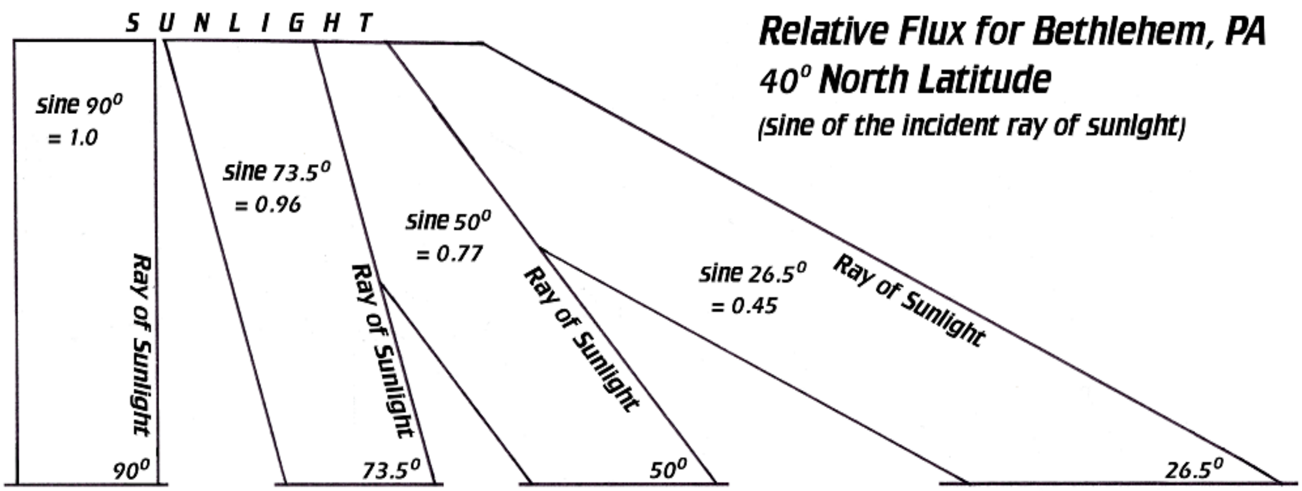
All five curves should be plotted on the same graph and using a key, identified with respect to latitude. You should plot 13 points for each latitude, repeating March 21. Draw smooth curves through the respective data points for each separate latitude sequence. Use the tables of data found in the back of this exercise to construct the graphs if the information is not gathered through a planetarium demonstration. Color code your curves to lessen any confusion in interpretation. Create a key which will allow you to identify each curve according to sunrise, sunset, and latitude.

Please note that if your plotted curves do not appear smooth and symmetrical with each other, you have either plotted a point incorrectly, calculated the data point incorrectly, or have a combination of both errors. In the altitude graph, the plots should look perfectly symmetrical if completed in a large graphical format as the instructions advise. Consult your instructor if a symmetrical pattern does not emerge.

In the length of the day graph, it will be very difficult to connect the low latitude points using a curve because of their closeness to the mean position of 12 hours of daylight. You may use straight lines instead. Use curves for 40 degrees north and 66-1/2 degrees north.

Calculating the Relative Energy Flux at Noon

The concept of the relative energy flux allows one to quantify the amount of energy being received at a location relative to a position on the Earth where the sun would be found overhead. It is simply to calculate. Take the sine of the altitude of the sun at noon, and you've got it. If a percentage is desired, simply multiply by 100. Keep in mind that the sine of 90 degrees, when the sun would be directly overhead, equals a relative flux of one (100 percent). The sine of 0 degree, where the sun would be on the horizon, would equal a relative flux of zero (0 percent)..



Data for Graphing the Seasons

Latitude 40^o N	**Azimuth of Sunrise**	**Time of Sunrise**	**Noon Sun Altitude**	**Relative Flux**	**Noon Azimuth**	**Time of Sunset**	**Azimuth of Sunset**	**Length of Day**
January 21			**30^o**		180^o			
February 21			**39^o**		180^o			
March 21 **Start Graph Here**	90^0	06:00	**50^o**		180^o	18:00	90^0	12 hours
April 21			**61^o**		180^o			
May 21			**70^o**		180^o			
June 21	57^o	04:30	**73-1/2^o**		180^o	19:30	303^o	15 hours
July 21			**70^o**		180^o			
August 21			**61^o**		180^o			
September 21	90^0	06:00	**50^o**		180^o	18:00	90^0	12 hours
October 21			**39^o**		180^o			
November 21			**30^o**		180^o			
December 21	123^o	7:30	**26-1/2^o**		180^o	16:30	237^o	9 hours

Latitude 66-1/2º N	Azimuth of Sunrise	Time of Sunrise	Noon Sun Altitude	Relative Flux	Noon Azimuth	Time of Sunset	Azimuth of Sunset	Length of Day
January 21			**3-1/2º**		180º			
February 21			**12-1/2º**		180º			
March 21 **Start Graph Here**	90^0	06:00	**23-1/2º**		180º	18:00	90^0	12 hours
April 21			**34-1/2º**		180º			
May 21			**43-1/2º**		180º			
June 21	0º	0:00	**47º**		180º	24:00	0º	24 hours
July 21			**43-1/2º**		180º			
August 21			**35-1/2º**		180º			
September 21	90^0	06:00	**23-1/2º**		180º	18:00	90^0	12 hours
October 21			**12-1/2º**		180º			
November 21			**3-1/2º**		180º			
December 21	180º	12:00	**0º**		180º	12:00	180º	0

Latitude 23-1/2º N	Azimuth of Sunrise	Time of Sunrise	Noon Sun Altitude	Relative Flux	Noon Azimuth	Time of Sunset	Azimuth of Sunset	Length of Day
January 21			**46-1/2º**		180º			
February 21			**55-1/2º**		180º			
March 21 **Start Graph Here**	90^0	06:00	**66-1/2º**		180º	18:00	90^0	12 hours
April 21			**77-1/2º**		180º			
May 21			**86-1/2º**		180º			
June 21	64º	05:30	**90º**		----	18:30	296º	13 hours
July 21			**86-1/2º**		180º			
August 21			**77-1/2º**		180º			
September 21	90^0	06:00	**66-1/2º**		180º	18:00	90^0	12 hours
October 21			**55-1/2º**		180º			
November 21			**46-1/2º**		180º			
December 21	116º	06:30	**43º**		180º	17:30	244º	11 hours

Latitude Equator 0º	Azimuth of Sunrise	Time of Sunrise	Noon Sun Altitude	Relative Flux	Noon Azimuth	Time of Sunset	Azimuth of Sunset	Length of Day
January 21			**70º S**		180º			
February 21			**79º S**		180º			
March 21 **Start Graph Here**	90^0	06:00	**90º**		**----**	18:00	90^0	12 hours
April 21			**79º N**		0º			
May 21			**70º N**		0º			
June 21	66-1/2º	06:00	**66-1/2ºN**		0º	18:00	293-1/2º	12 hours
July 21			**70º N**		0º			
August 21			**79º N**		0º			
September 21	90^0	06:00	**90º**		----	18:00	90^0	12 hours
October 21			**79º S**		180º			
November 21			**70º S**		180º			
December 21	113-1/2º	06:00	**66-1/2º S**		180º	18:00	266-1/2º	12 hours

Latitude 23-1/2º S	Azimuth of Sunrise	Time of Sunrise	Noon Sun Altitude	Relative Flux	Noon Azimuth	Time of Sunset	Azimuth of Sunset	Length of Day
January 21			**86-1/2º**		0º			
February 21			**77-1/2º**		0º			
March 21 **Start Graph Here**	90^0	06:00	**66-1/2º**		0º	18:00	90^0	12 hours
April 21			**55-1/2º**		0º			
May 21			**46-1/2º**		0º			
June 21	64º	06:30	**43º**		0º	17:30	296º	11 hours
July 21			**46-1/2º**		0º			
August 21			**55-1/2º**		0º			
September 21	90^0	06:00	**66-1/2º**		0º	18:00	90^0	12 hours
October 21			**77-1/2º**		0º			
November 21			**86-1/2º**		0º			
December 21	116º	05:30	**90º**		----	18:30	244º	13 hours

Name ________________________________ Date _______________ Moravian University

QUESTIONS DEALING WITH THE ALTITUDE GRAPH

1. __________ What is the altitude of the sun at noon on October 11 at 40^o N. latitude?

2. __________ What is the altitude of the sun at noon on October 11 at 66$^1/_2$^{o} N. latitude?

3. __________ What is the difference in the noontime altitude of the sun at these two locations?

4. __________ What is the angular difference in the two latitude positions?

5. How are the answers to questions three and four related with respect to the change in latitude and the change in the sun's altitude?

   ____

6. __________ What is the total change in altitude for the sun between summer and winter solstice during the course of the year for each latitude position that you plotted?

7. How is this amount of change related to the Earth's axial tilt?

   ____

8. What two extremes in latitude (limits) are suggested by the graph with respect to the sun appearing at the zenith? An extreme in this case would only happen once a year.

   ____

   ____

9. What two extremes in latitude (limits) are suggested by the graph with respect to the sun appearing on the horizon? An extreme in this case would only happen once a year.

   ____

   ____

10. How is the curve for 23 ½° N latitude related to the curve for 23 ½° S? What does this tell you about the seasonal effect occurring at the same latitude but in opposite hemispheres?

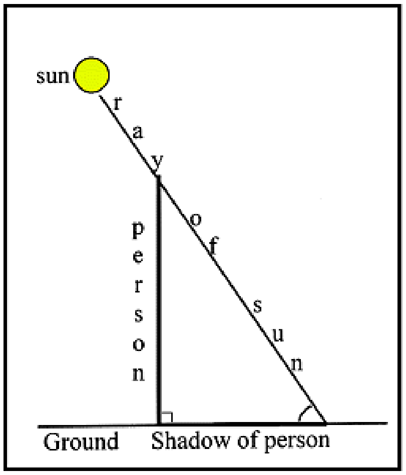
    ____

    ____

    ____

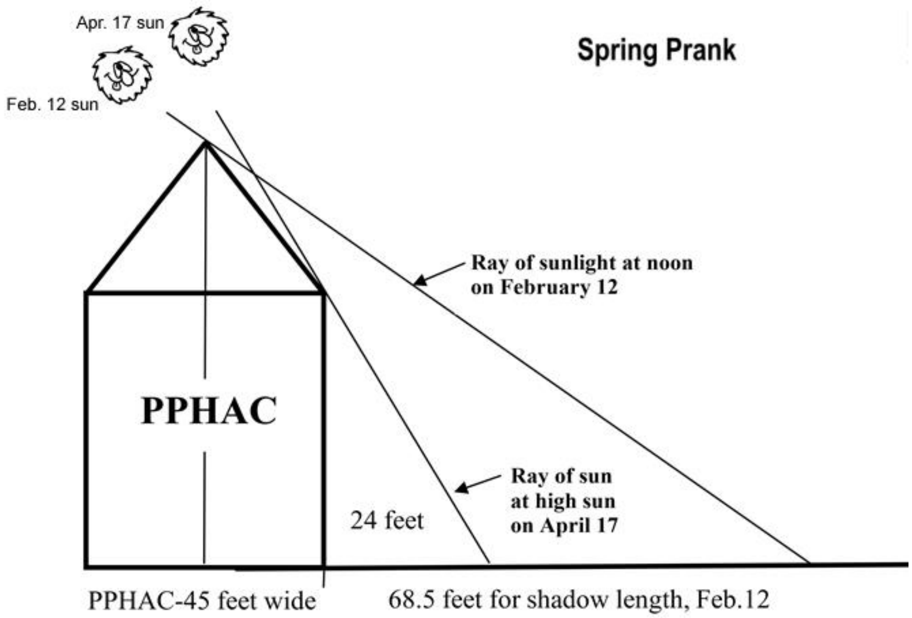
    Summer solstice occurs in the N. hemisphere __________ S. hemisphere ___________

11. Determine mathematically or by geometric construction (see the diagram on the next page) the length of the shadow that you cast in a standing position at noon on the first day of spring. Consider your location to be at Moravian University in Bethlehem. PA. In a geometrical construction, you must establish a scale. If you use trigonometry, consider the tangent function and show all work on the next page or provide an accurate sketch on a separate sheet of paper.



12. An enterprising junior at Moravian University who enjoys rock climbing wants to pull an "end of the spring term prank" by having his picture taken on the rooftop of PPHAC on North Campus. Afraid that he may not have brought enough rope for the descent from the midpoint of the roof where he wants the picture taken, he needs to know the length of the roof's slope and the height of the building from the bottom of the roof to the ground. He also doesn't want to arouse suspicion by asking the research librarian at Reeves to show him the building plans, so he decides to measure it himself. The side of the building is completed with a very long measuring tape. Then, he makes two high sun observations, one on February 12 and the other on April 17. He notes the length of PPHAC's shadow at 68.5 feet and 24 feet, respectively. Will the 75 feet of rope that he has stored in his dorm be sufficient for getting down safely?

    a. What is the rappel length from a point midway between PPHAC's two sides? _______________
    b. Will the student have enough rope to make a successful descent? __________



13. A planet has an axial tilt of 35°. State the location of that planet's
    ___________ Tropic of Cancer
    ___________ Tropic of Capricorn
    ___________ Arctic Circle
    ___________ Antarctic Circle

14. Mars has an axial tilt of 24°. Its average distance from the sun is 1.54 AU, and its orbital period is 687 days or nearly two Earth years. State one similarity and one difference in the Martian seasons.
    Similarity ____
    Difference
    ____

15. When the sun is at the zenith, the relative flux is equivalent to 1 or 100 percent. At the latitude of Bethlehem, PA the relative flux at noon on the winter solstice is 50 percent of what it is at noon on the summer solstice. With half of the solar energy reaching Bethlehem at the winter solstice, why does it become so cold in the winter?
    ____
    ____

QUESTIONS CONCERNING THE SUNRISE/SUNSET GRAPH

16. ___________ Where on Earth does the duration of daylight vary from 0-24 hours?

17. ___________ Where on Earth is the duration of daylight 12 hours all year long?

18. Around what times of the year do the sunrise and sunset times cluster? Why?
    ____

____

____

19. ___________ On a given day the sun rises at an azimuth of 83^o. What is the sunset azimuth of sunset on that same day?

20. Would the sun set earlier or later (circle one) in Miami, FL (26^o N) than in Bethlehem, PA (40^o N) on the first day of summer? Why?

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____

21. The Scandinavian countries of Denmark, Norway, and Sweden experience a higher suicide rate at a particular time of the year. Propose the time of year and a hypothesis to account for this situation.

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