Senior 1

Appendices:
Cluster 4
Exploring the Universe

SLA
Student Learning Activity

Astrolabe Construction

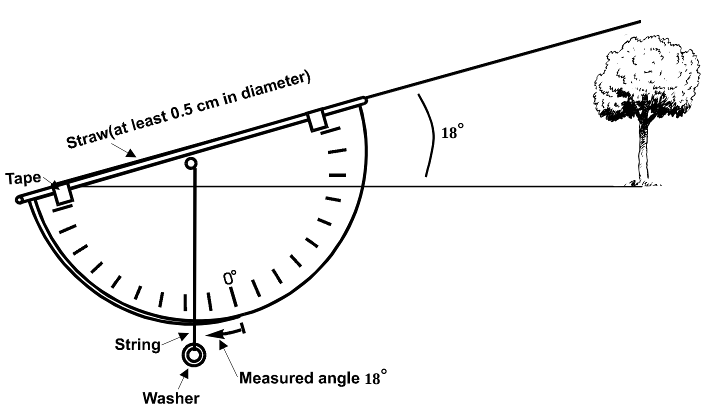
Materials:

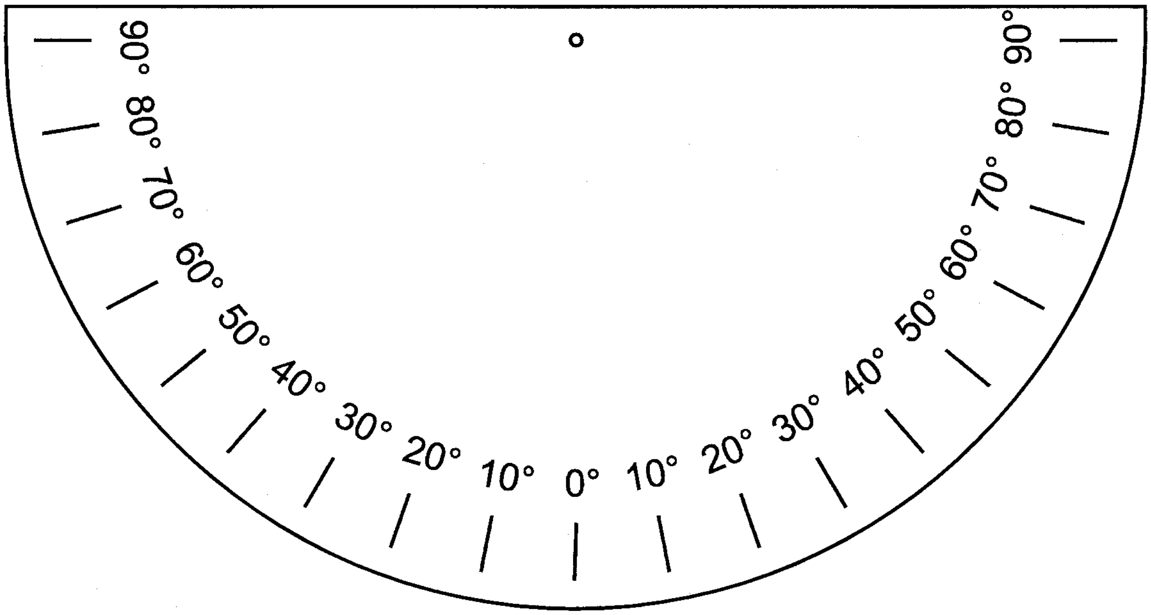
- thick corrugated cardboard (about 8.5" x 11" or similar)
- scissors
- 20 cm of thin string or coloured fishing line
- weight (washer, nut, lead sinker, or similar object that can be tied onto the string)
- large drinking straw (at least 0.5 cm in diameter)
- glue
- transparent tape
- small block of 0.5" plywood or pressboard (optional)

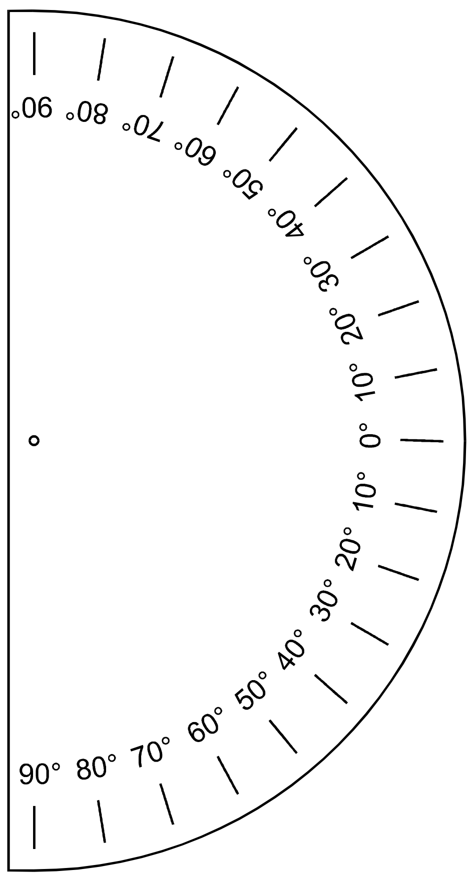
Directions:

1. Carefully cut out one of the astrolabe templates on the following page, according to desired size.
2. Glue the template securely to the cardboard, and then cut out the template/cardboard in the semi-circular shape of the template. Discard the remainder appropriately.
3. Carefully pierce a hole at the ‘o’ in the centre of the template. You may wish to ask for assistance in this.
4. Put the string through the hole and tie a knot, then tape it in place on the reverse side of the template. The string should now hang freely on the front side of the template.
5. Tie the weight to the end of the string so that it hangs at least 10 cm below the edge of the astrolabe.
6. Tape (or glue) the straw securely along the flat side of the astrolabe, and test to ensure that you can see through the straw.
7. For a longer-lasting device, you may wish to mount it on a semi-circular piece of plywood that has been carefully cut to fit the size of the template. **Use caution when working with hand tools.**

The astrolabe that you have constructed should appear similar to the one pictured below. You should easily be able to sight large objects through the straw. Your device is now ready to be field-tested with an activity involving the *altitude* of objects above the horizon.




90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°


90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°

SLA
Student Learning Activity

Locating Celestial Objects Using a System of Coordinates

Purpose:

To use the constructed astrolabe and an orienteering-type compass to locate and determine the *altitude* and *azimuth* of a selection of objects in the night sky.

Note: If the activity cannot be done at night, substitute objects that are visible around you during the day, (e.g., buildings, trees, etc.). This is not, however, the most desirable option.

Caution: DO NOT directly observe the Sun as part of this activity.

Materials:

- student-constructed astrolabe
- orienteering-type compass for measuring azimuth
- logbook or chart to record measurements (see sample below)
- simplified star chart or planisphere

Procedure:

1. Select at least five objects in the night sky that you wish to locate and that will be visible at the time you are doing the activity: the Moon; bright planets such as Venus, Mars, Jupiter and Saturn; easy to find stars such as Polaris (the North Star), Vega, and Arcturus are the easiest to locate until you are more familiar with the night sky at your location.
2. Using the compass, determine the *azimuth* of the object by visually tracing a line from the object in the sky straight down to the nearest horizon point, and reading its compass bearing (e.g., 90 degrees would be due east, 180 degrees would be due south, etc.). Record this in your chart or logbook.
3. Using the “hand-angle technique” that you have learned and practised, estimate the *altitude* of the object of interest. Record your estimates in the chart or a personal observation logbook.
4. Using the astrolabe, look through the straw until you can see the object centred in the field of view. While holding the instrument steady, use your free hand to pinch the string against the scale on the astrolabe until you are able to record the *altitude*. Repeat this at least two more times for the same object, and average the three readings in order to increase the precision.
5. Be prepared to discuss with a classmate or group how you determined your readings. It may be useful to arrange for you and another classmate to observe the same selection of objects at the same time, and compare your results.

Data Chart: Azimuth and Altitude Readings

Date and Time of Observation	Object Viewed	Azimuth (in degrees) from Compass	Altitude Estimate Using Hand-Angle Technique	Altitude as Measured by Astrolabe

SLA Student Learning Activity

Observing and Charting the Motions of Celestial Objects

Purpose:

To observe and record, over a period of time, the apparent motions of easily visible celestial objects, and to organize data for eventual display. The three objects of interest here will be the Sun, Moon, and at least one bright planet (e.g., Venus, Mars, Jupiter, Saturn).

Materials:

- student-constructed astrolabe
- orienteering-type compass
- logbook or data chart for recording (see below)
- seasonal star charts (or planetarium software)
- plotting software such as *Excel™* or *Curve Expert™*

Procedure:

Tracking the Moon:

1. Use a calendar to determine when the next “New Moon” occurs. This will be Day 1 of the observation program.
2. Over a period of 14 days (or longer if possible), and always observing at the *same time* each evening, determine the altitude and azimuth of the Moon using your astrolabe and compass. A convenient time may be 8 p.m. in the fall or spring or 6 p.m. in the winter months.
3. In your data chart or logbook, record the position of the Moon as co-ordinates (e.g., *altitude* 12°, *azimuth* 175°) (see chart below).
4. Sketch the appearance of the Moon and record the percentage of its face that is illuminated (i.e., First Quarter Moon is 50% illuminated from our point of view, Full Moon is 100% illuminated, etc.).
5. Continue to record these data for 14 successive nights. If cloudiness is a problem, skip that day in the data entries. If you cannot observe, obtain a classmate’s data.
6. Plot your data (see graphs below). On the first graph, plot the Moon’s *Azimuth* vs. the *Day Number*. On the second graph, plot the Moon’s *Altitude* vs. *Day Number*. Make your dots large enough to see clearly on the graph, and join them together with straight lines.

Extension:

1. Create a “rose petal diagram” by plotting your data on circular *polar graph paper* if available. Use the outer circle to mark off your azimuth directions (i.e., 0° is north, 90° is east, etc.). The lines that go out from the centre will be your altitude (with 0° altitude at the centre of the circle and 90° altitude at the outer edge of the circle).

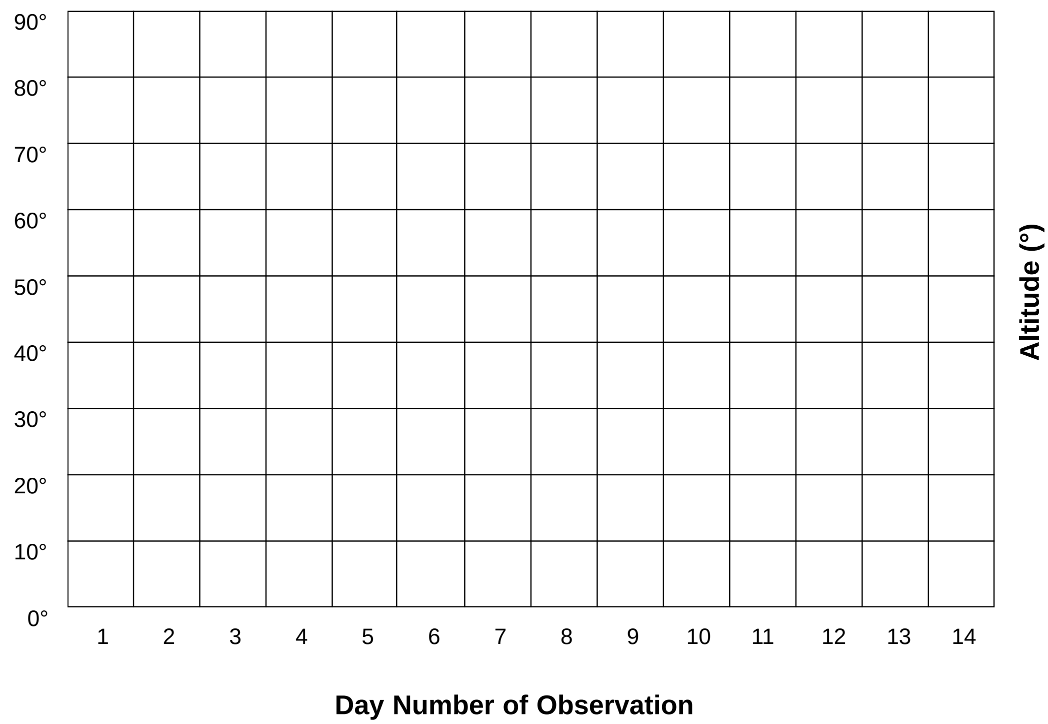
2. Investigate a second set of co-ordinates used by astronomers — *Right Ascension* and *Declination*. Instead of changing with time as altitude and azimuth do, these co-ordinates are similar to longitude and latitude on the Earth. They remain constant as the Earth rotates and revolves around the Sun. Good star charts will include the grid lines of right ascension and declination.
3. Plot the position of the Moon or planets over a series of evenings directly on a simplified star map. This is a good way of tracking the apparent movements of these solar system objects. If you are really adventurous, get some data on large asteroids (e.g., Vesta, Ceres) and follow their movements from night to night.

Data Table: Lunar Observations Over 14 Days

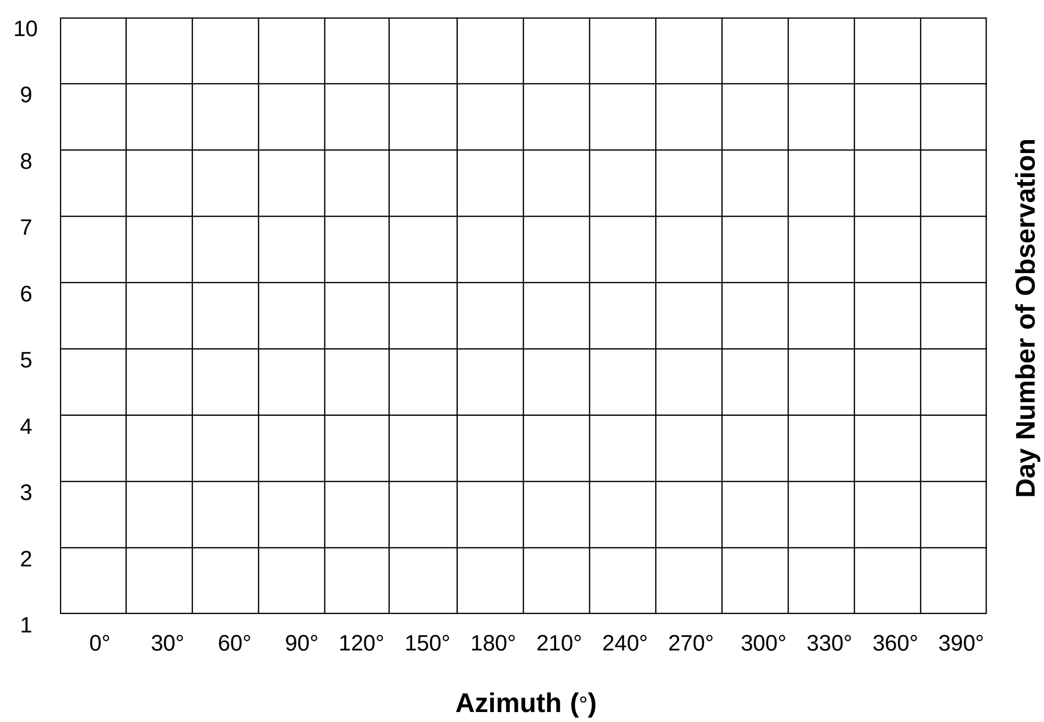
Date and Time of Observation	Altitude of Moon	Azimuth of Moon	Moon's Appearance	Percentage of Illumination of Moon

Data Plots of Lunar Observations:

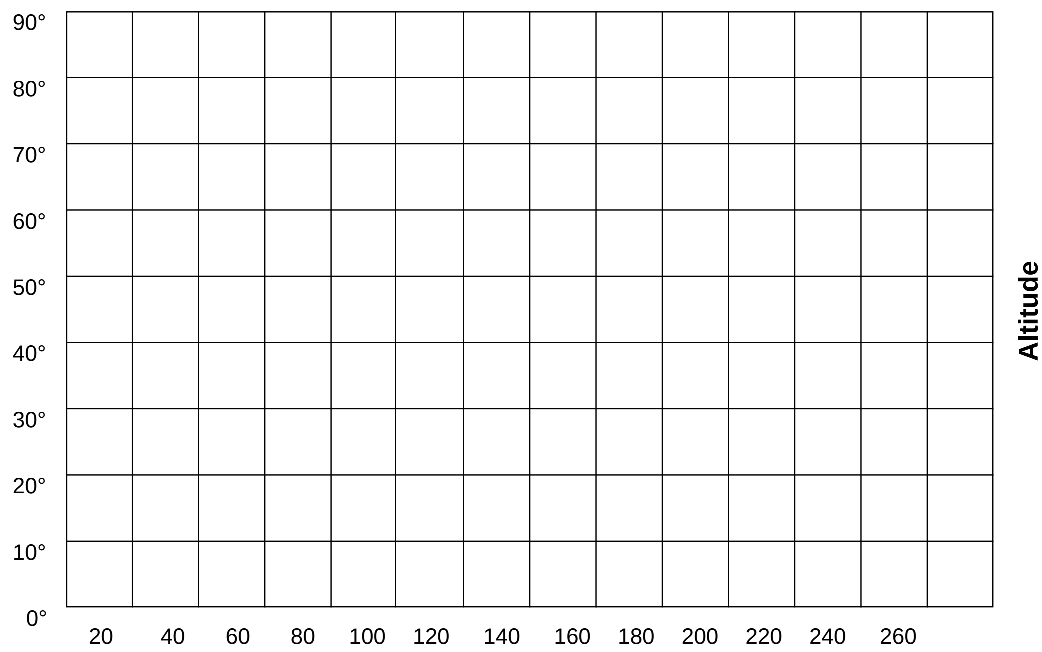
Altitude of Moon Above Horizon Over 14-Day Period



Azimuth of Moon Above Horizon Over 14-Day Period



Altitude vs. Azimuth for the Moon Over 14-Day Period



Extension:

Plot additional graphs from the data you've collected on the position of a planet such as Venus, Mars, or Jupiter. If you choose to plot position data for the Sun, it is strongly recommended that you consult tables of data available from such sources as the Royal Astronomical Association of Canada (http://www.rasc.ca).

Make copies of the following blank chart to collect and organize your data.

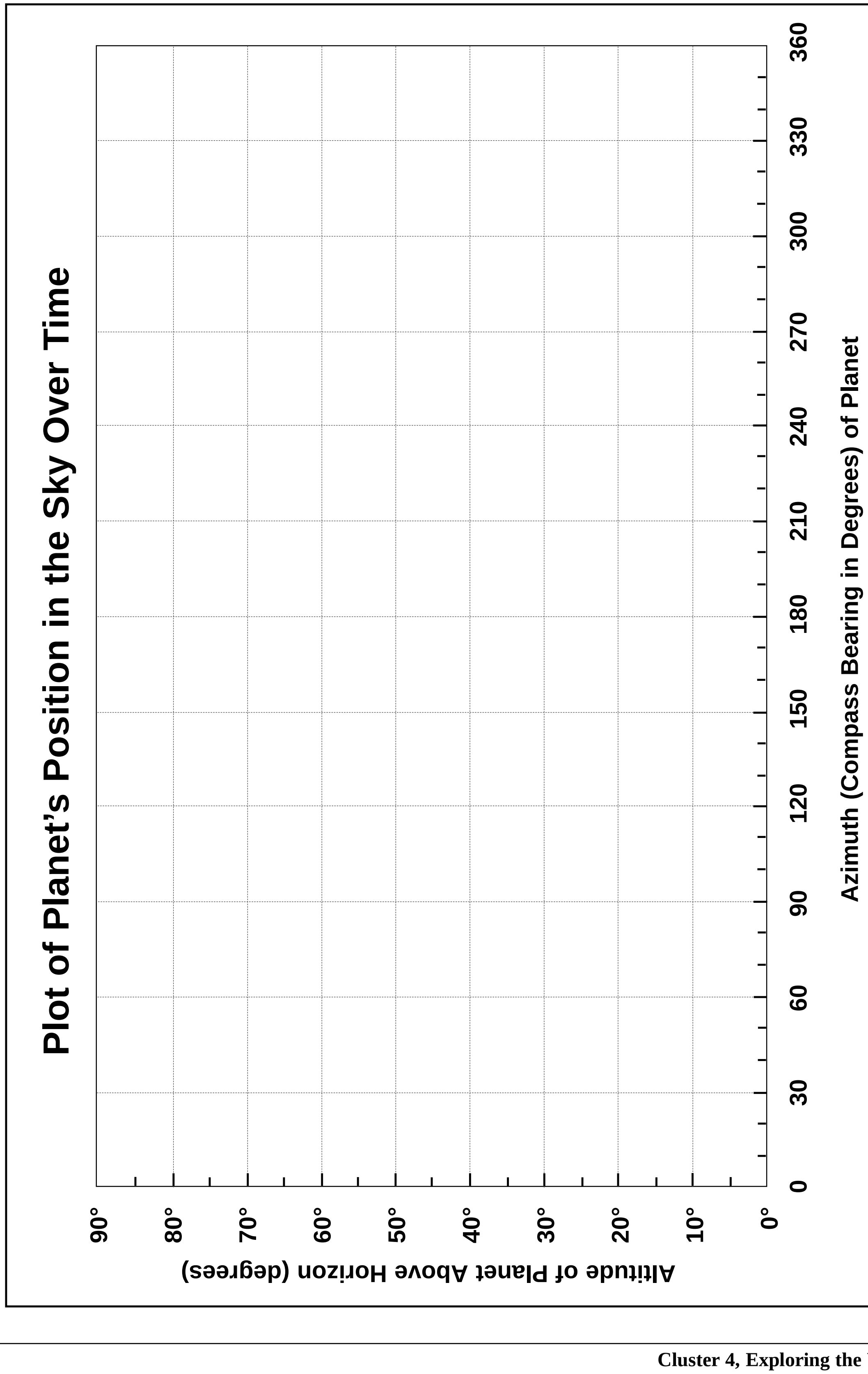
Data Table #__: Planet Observations Over Time

Name of Planet or Other Celestial Object: ____________________________________

Date and Time of Observation	Altitude of Planet or Object	Azimuth of Planet or Object	Right Ascension (optional)	Declination (optional)

Planet's Position Over Time: Altitude/Azimuth

Plot #___:



Questions:

1. You see a certain star directly overhead while you are observing. What is the name given to this location in the sky, and what would the star's altitude be?

   ____

   ____

2. What are the co-ordinates of a planet that is visible in the southeast and is estimated to be halfway up in the sky from the horizon?

   Altitude: ________________________ Azimuth: ________________________

3. What are the co-ordinates of the Moon when its position is due east and 10° above the horizon?

   Altitude: ________________________ Azimuth: ________________________

4. Wherever you are in the Northern Hemisphere, Polaris (the "North Star") always approximates true north. (It is actually off true north by about one-fourth of a degree.) You can also determine your latitude by measuring the altitude of Polaris using the techniques you have already learned.

   If you lived at Cross Lake, Manitoba (latitude is 54.0° N), what would be the altitude/azimuth of Polaris at all times?

   Altitude: ________________________ Azimuth: ________________________

5. Based on your observation of the Moon's position over a 14-day period, describe the changes you observed in its position from night to night (all observations made at the same time each night).

   ____

   ____

   ____

   ____

   ____

   ____

   ____

6. If you observed the Moon's azimuth to be 240° at 8 p.m. on one night, predict what its azimuth would be on the next two consecutive nights at the same time.

   Azimuth Day 2: ___________________ Azimuth Day 3: ___________________

Motion of the Sun as Seen from Earth

SLA
Student Learning Activity

Purpose:

To collect, graphically present, and interpret data on the position of the Sun over the course of a school year. If time does not permit this, it is advisable, at the very least, to collect data on the Sun's position during the course of a single day.

Note: If you are observing for a period of hours over just one day, use the last two columns of the data chart only.

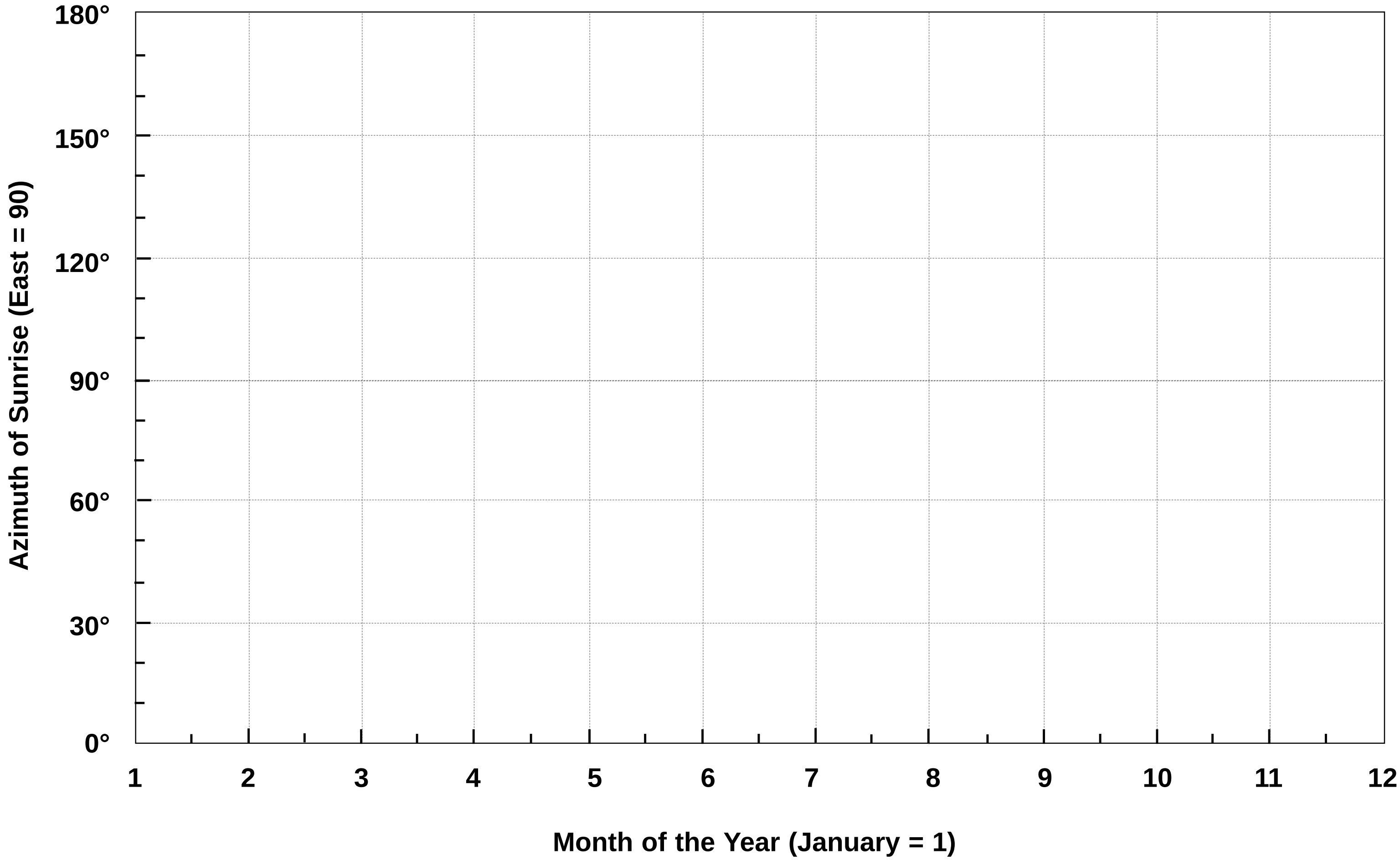
Materials:

- access to a database of the Sun's rising/setting positions or direct observations (conducted with all necessary safety precautions)
- student-constructed astrolabe
- orienteering-type compass
- logbook or data chart (see chart on the following page)
- sunrise/sunset charts (or a planetarium software program)
- plotting software such as *Excel™* or *Curve Expert™*

Data Table: Solar Observations Over Time

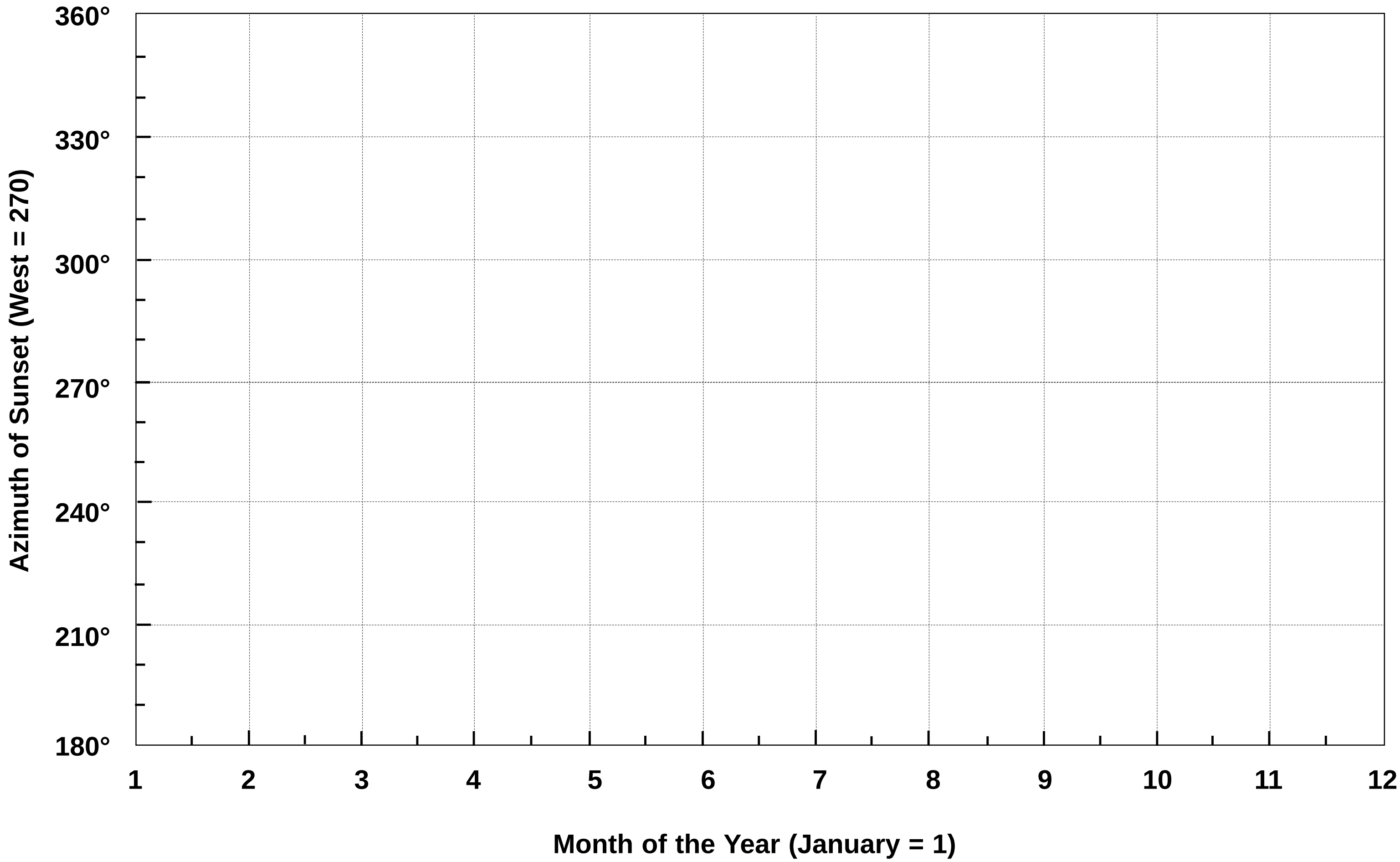
Date and Time of Observation	Azimuth of Sunrise	Azimuth of Sunset	Altitude of Sun (for single day observing)	Azimuth of Sun (for single day observing)

Graph of Azimuth of Sunrise Over 12 Months



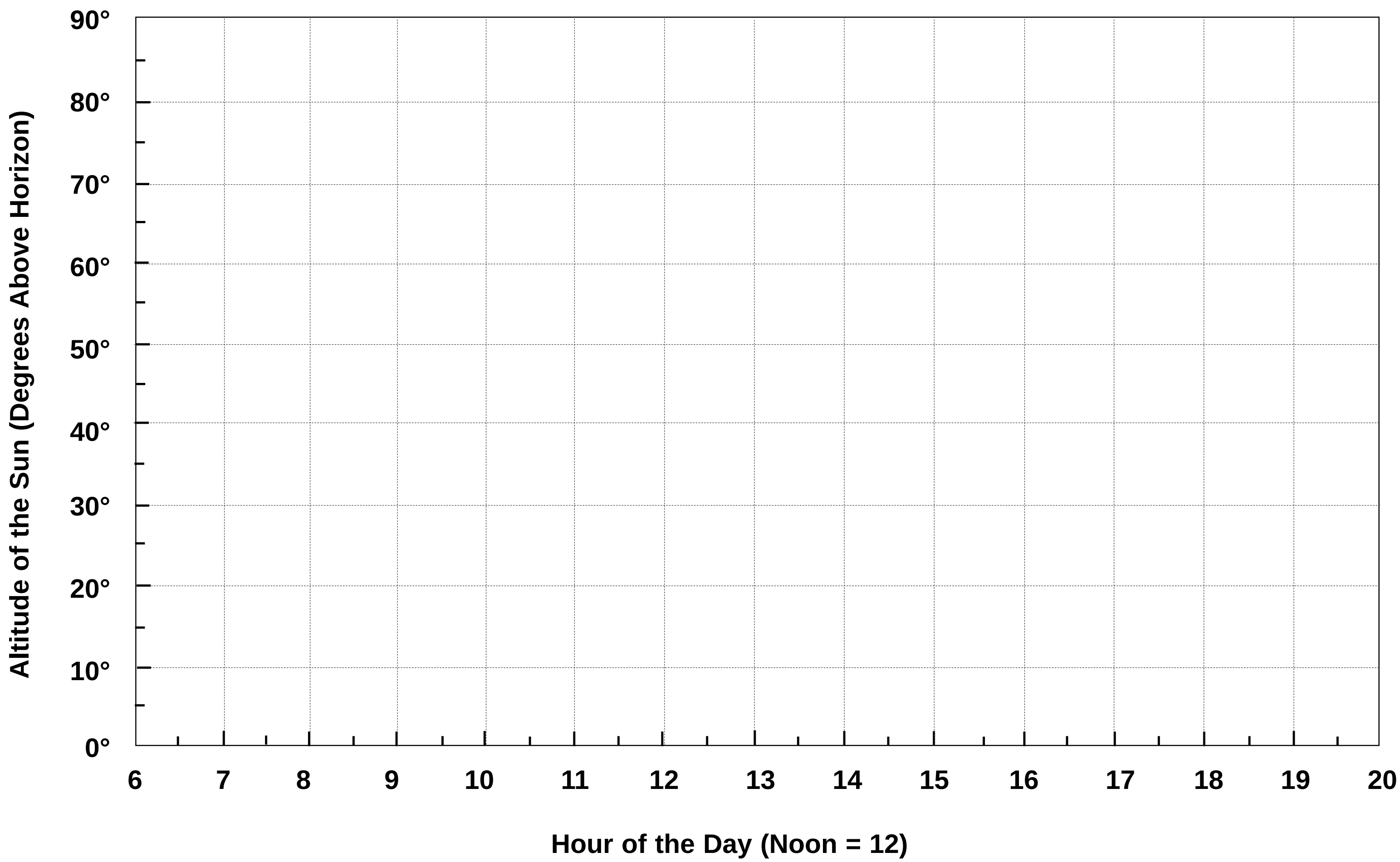
Azimuth of Sunset

Graph of Azimuth of Sunset Over 12 Months



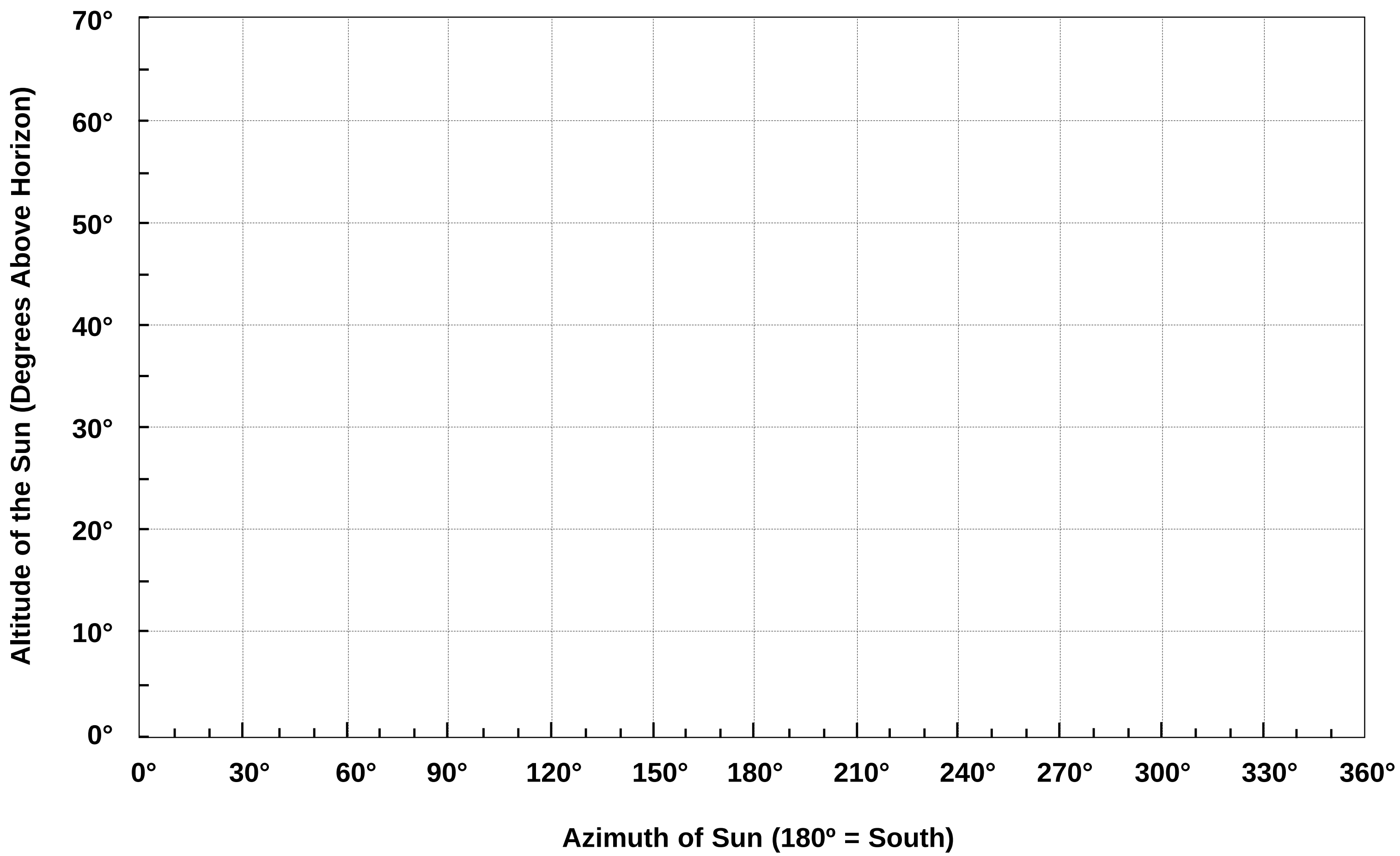
Sun's Altitude

Graph of Altitude of Sun Over 12-Hour Period



Sun's Altitude and Azimuth

Graph of Sun's Position in the Sky Over One-Day Period



Follow-up Questions:

1. Over the course of a period of months, what changes did you observe in

   the position of the Sun at sunrise?____

   ____

   ____

   the position of the Sun at sunset? ____

   ____

   ____

2. In which two months of the year does the Sun rise and set *exactly* in the east (90) and west (270) respectively?

   _________________________________ and _________________________________

3. What is the significance of the two times of year mentioned in your answer to #2 above? What is the significance to the calendar?

   ____

   ____

   ____

   ____

4a. During what season of the year does the Sun rise furthest to the *north* on the horizon?

   ____

4b. During what season of the year does the Sun set furthest to the *south* on the horizon?

   ____

4c. Using your own background knowledge or independent research, what is responsible for the changes you observed in the rising/setting of the Sun over a period of months?

   ____

   ____

   ____

   ____

5. If you completed the data set on the altitude/azimuth of the Sun over a 12-hour period, answer the following based on your observations.
   a. During what season of the year did you make these observations and/or collect your data?

      ____

   b. At what time of day did the Sun reach its maximum altitude according to your data?

      ____

   c. If your time in part (b) above was not 12:00 noon local time, how would you explain this to a friend?

      ____

6. The planet Venus is unique in the solar system — its day is actually *longer* than its year! A day (sunrise to sunrise) on Venus lasts 243 days. Venus also has *retrograde rotation*, which means the planet rotates in a direction opposite to that of the Earth. On Venus, the Sun rises in the west and sets in the east! If you were an observer on Venus, what changes would you expect to see in your graphs completed for this learning activity?
   - ____
     ____
     ____
   - ____
     ____
     ____
   - ____
     ____
     ____
   - ____
     ____
     ____

SLA
Student Learning Activity

Monitoring the Retrograde Motion of the Planet Mars

Background Information:

The graph below (Figure 1) is a representation of the movement of the planet Mars over an 18-month period during 1988 — the last time the retrograde motion of Mars was easily visible to Earth observers. The next best time will be in 2005, and every 17 years after that. Although this phenomenon can always be seen, it is best observed when Earth and Mars are at their closest approach.

The motion of Mars as observed from Earth can be described using a race analogy. Imagine two runners named Tellus (the Earth) and Areos (Mars) who are racing around a track that is almost perfectly circular. Rather than allowing Areos (the outside runner) to start the race further along the track than Tellus (the inside runner), the two runners start side by side. Since Tellus can run faster than Areos (because he is closer to the Sun), Areos quickly begins to fall behind. As Tellus gains on Areos, there will be a short period of time where it will appear as though the outside runner slows down, stops momentarily, and then goes backwards. This is only an illusion, of course, as both runners are always travelling forward around the track.

The graph below shows where Mars appears to slow down, then stops, and reverses direction for a brief period before resuming its normal movement across the sky. We call this *retrograde motion*. In this observational activity, you will be plotting some data in order to examine something that was a very difficult idea for ancient astronomers to explain.

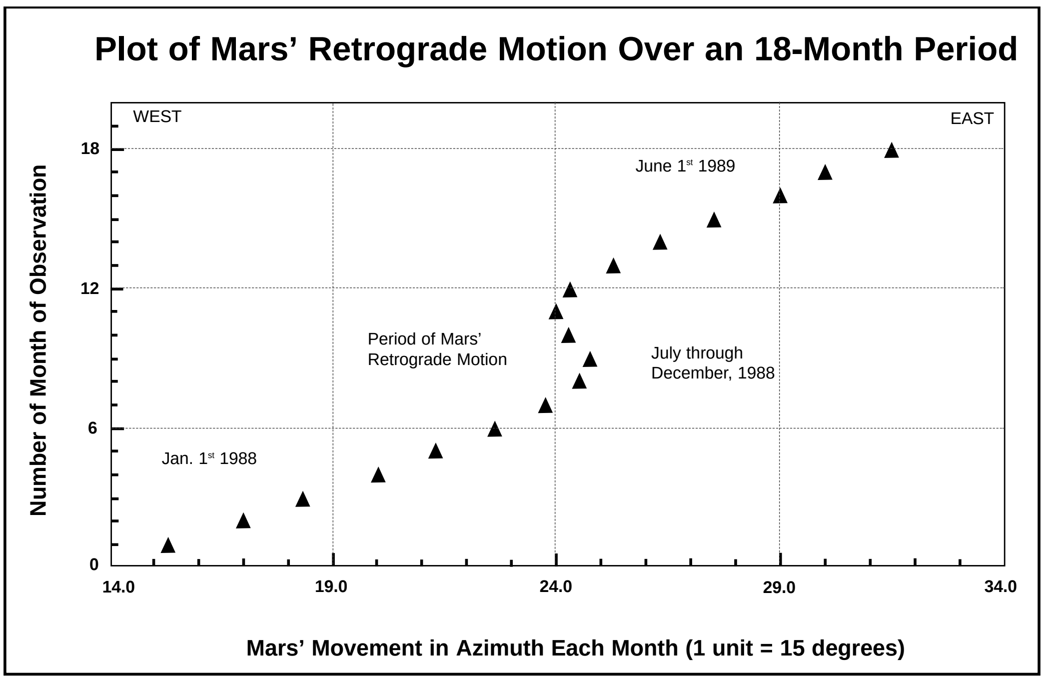


Figure 1: Retrograde Motion of Mars

Does This Planet Have Retrograde Motion?

Purpose:

To monitor and record the motion of Mars over time to better understand retrograde motion.

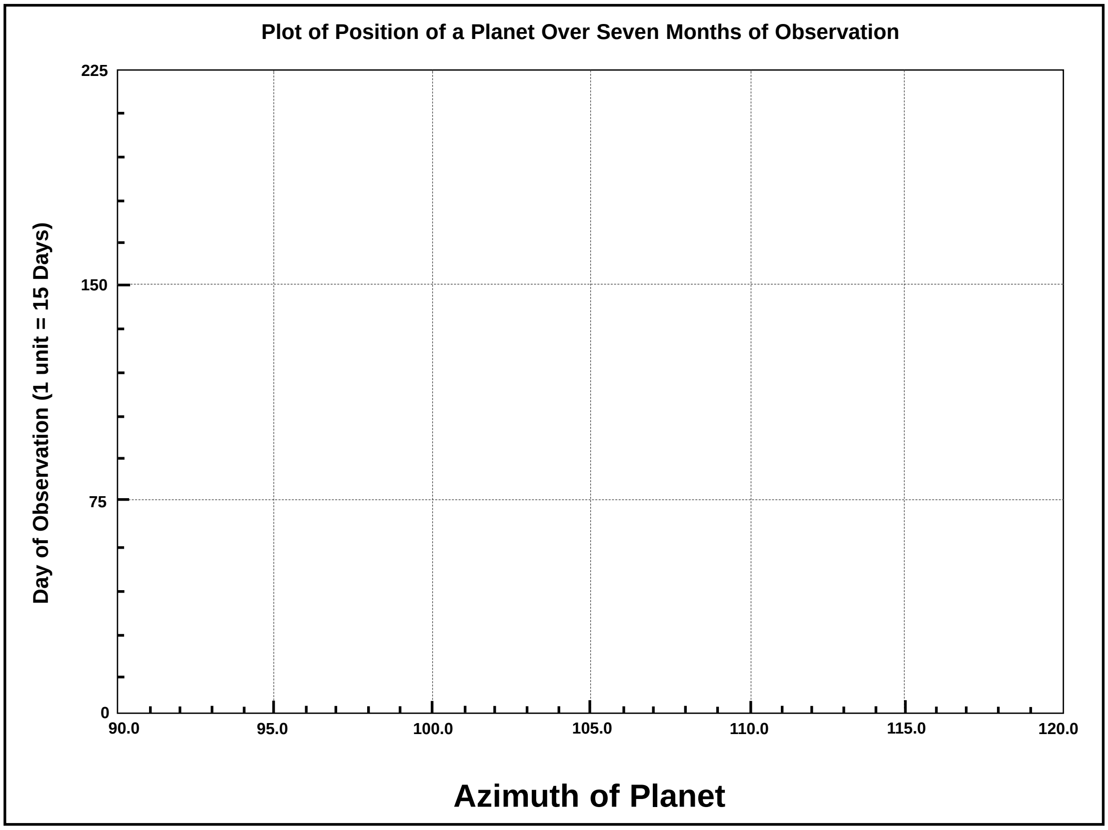
Procedure:

Using the data set that appears below, plot each position carefully on the blank graph on the next page. Label each point you plot with the date of the observation to better simulate actual measurements. Join all of the points with a smooth line.

Data Chart: Planet Positions

Date of Observation	Azimuth of Planet
July 1	112.5°
July 15	105.0°
August 1	98.25°
August 15	94.0°
September 1	93.75°
September 15	94.0°
October 1	97.5°
October 15	102.0°
November 1	108.75°
November 15	109.0°
December 1	101.25°
December 15	95.0°
January 1	90.0°

Position of Planet



Follow-up Questions:

1. How does your plot compare with that of Mars (see Figure 1)? Identify at least two similarities and two differences.

____

____

____

____

2. Does this planet revolve around the Sun in the same direction as the Earth? Justify your answer based on the data you have presented above.

____

____

____

____

3. Write a simple procedure to make planetary observations (of Mars or Jupiter), including recording and graphing the data, and presenting the graph to your classmates.

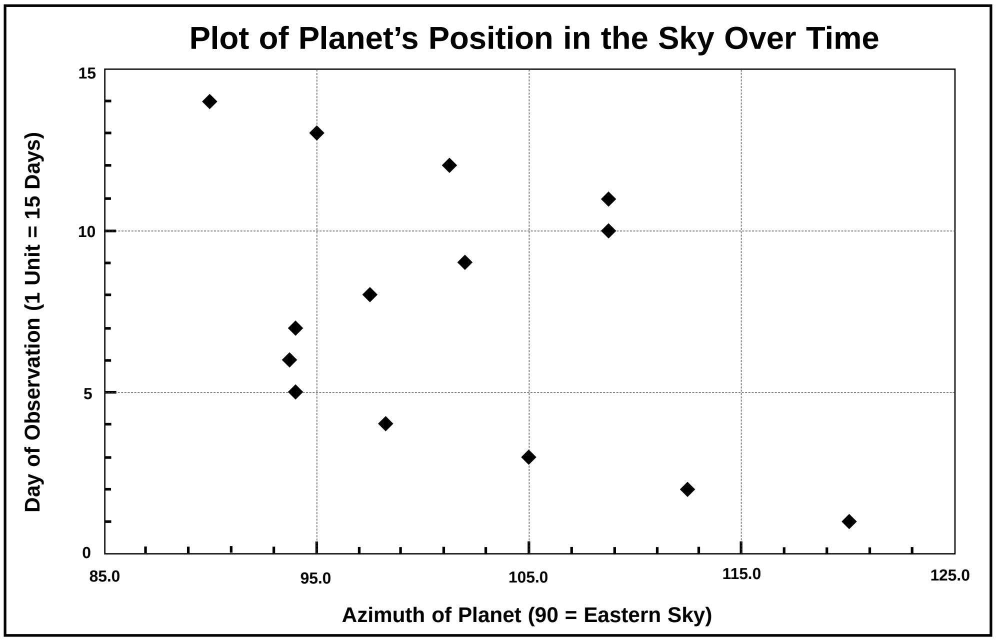
   - ____
     ____
   - ____
     ____
   - ____
     ____
   - ____
     ____

4. Imagine that you are one of the ancient Greek astronomers (perhaps Ptolemy) and you are seeking an explanation as to why Mars periodically and mysteriously slows down, stops moving for a couple of weeks, reverses its motion against the background of distant stars, and then resumes its normal eastward movement across the sky. Furthermore, you have noticed by searching your records that this happens most dramatically every 17 years or so.

   Design a model of the cosmos that will satisfy the best minds of your age. Research the topic of *retrograde motion* and see how the early astronomers solved this problem. Report the five (5) most significant ideas from your research in the space below.

   - ____
     ____
   - ____
     ____
   - ____
     ____
   - ____
     ____
   - ____
     ____

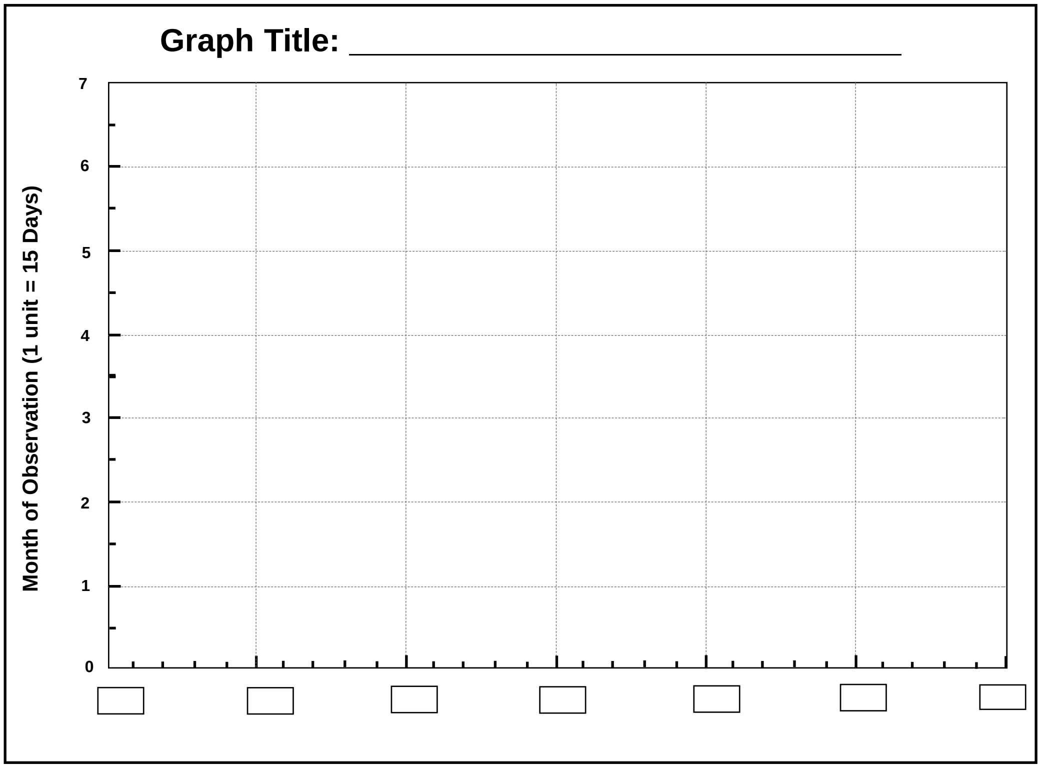
5. Compare your graph to the one that appears below. After examining your own work, comment on how successful your graphing technique was, and make a few notes for the future. Complete the checklist of graphing skills below.



Checklist of Graphing Skills	Name: ____________			
	NI	**S**	**E**	**Comments**
Standard Elements — selects appropriate type of graph				
— uses appropriate scale for each axis				
— chooses appropriate origin and intervals along each axis				
— labels axes clearly				
— states in the graph's main title the relationship between axes				
— places independent variable on the *x*-axis				
— places dependent variable on the *y*-axis				
— includes key or legend when necessary				
Data — plots data accurately				
— depicts trends (when applicable)				
Presentation				
— uses space on the graph appropriately				
— uses space on the paper appropriately				
— graphs neatly and clearly				
— depicts trends clearly, so they are easy to interpret				

NI — Needs Improvement
S — Satisfactory
E — Excellent

6a. Make any necessary modifications to your plot on the blank graph presented below. Be sure to base your changes on the items mentioned in your "Checklist of Graphing Skills."



6b. Note the changes made to your graph in the space provided below.

- ______________________________
  ____
  ____
- ______________________________
  ____
  ____
- ______________________________
  ____
  ____
- ______________________________
  ____
  ____

SLA
Student Learning Activity

The Search for Extraterrestrial Intelligence — The Drake Equation

Background Information:

The search for extraterrestrial life usually generates a discussion of UFOs and the extent to which we believe in them. Internet sites provide information about the search for life in star systems beyond the solar system. Space probes sent from Earth are carefully sterilized so they do not contaminate any organism that may be contacted in space. Likewise, all incoming space probes are similarly sterilized for the same reason against what is called "back contamination" of the Earth.

The search for extraterrestrial intelligence (SETI) is an excellent example of how serious science can be distorted and corrupted by popularized accounts. The UFO debate is just one such situation. The SETI program is a well-funded attempt at scanning the heavens for transmissions that may originate from past or presently communicating intelligent lifeforms. One of the founding members of the SETI research community, Dr. Frank Drake, developed an interesting probability relationship that has become known as the *Drake Equation*. By entering values for certain symbols in this equation, one can speculate about the number of intelligent, communicating civilizations in our galaxy. An example appears in this learning activity (see the 1961 equation). The Drake Equation was developed as a way to focus on the key factors which determine how many intelligent, communicating civilizations there are in our own Milky Way galaxy.

If you are you interested in participating actively in the SETI program, log on to the Planetary Society website at http://www.planetary.org, and follow the SETI links from there. You will be looking for the seti@home hyperlinks.

The Drake Equation looks like this:

$$\mathbf{N_0 = N^*\ f_p\ n_e\ f_l\ f_i\ f_c\ f_L}$$

Where $\mathbf{N_0}$ = Number of intelligent, communicating civilizations in our Milky Way galaxy.

$\mathbf{N^*}$ = Number of stars in the Milky Way galaxy.

$\mathbf{f_p}$ = Fraction of **N** having planetary systems.

$\mathbf{n_e}$ = Number of planets per star capable of sustaining life.

$\mathbf{f_l}$ = Fraction of $\mathbf{n_e}$ where life evolves.

$\mathbf{f_i}$ = Fraction of $\mathbf{f_l}$ where intelligent life evolves.

$\mathbf{f_c}$ = Fraction of $\mathbf{f_i}$ that develops the means of radio frequency communication.

$\mathbf{f_L}$ = Fraction of a planet's natural history during which a civilization is actively communicating beyond itself into deep space.

The equation could be seen as providing answers to a number of questions.

N* represents the number of stars estimated to be in the Milky Way galaxy.

Question: How many stars are in the Milky Way galaxy?
Answer: Current estimates are 100 billion.

$\mathbf{f_p}$ is the fraction of stars that have planets around them.

Question: What percentage of stars have planetary systems?

Answer: Current estimates range from 20% to 50%.

$\mathbf{n_e}$ is the number of planets per star that are capable of sustaining life.

Question: For each star that does have a planetary system, how many planets are capable of sustaining life?

Answer: Current estimates range from 1 to 5.

$\mathbf{f_l}$ is the fraction of planets in $\mathbf{n_e}$ where life evolves.

Question: On what percentage of the planets that are capable of sustaining life does life actually begin and evolve?

Answer: Current estimates range from 100% (where life can evolve, it will) down to close to 0% (life is a very rare occurrence).

$\mathbf{f_i}$ is the fraction of $\mathbf{f_l}$ where intelligent life evolves.

Question: On the planets where life does evolve, what percentage of these evolve intelligent, self-aware lifeforms?

Answer: Estimates range from 100% (intelligence is such a survival advantage that it will certainly evolve) down to near 0%.

$\mathbf{f_c}$ is the fraction of $\mathbf{f_i}$ that communicate.

Question: What percentage of intelligent species have the means to communicate?

Answer: Estimates are from 10% to 20%.

$\mathbf{f_L}$ is the fraction of the planet's lifespan during which the actively communicating civilizations live.

Question: For each civilization that does develop the ability to communicate into deep space, for how long during the planet's life does the civilization last?

Answer: This is perhaps the toughest of all the questions to answer. If we take Earth as an example, the expected lifetime of our Sun and the Earth is roughly 10 billion years. So far, we have been communicating with radio waves for less than 100 years. How long will our civilization survive? Will we destroy ourselves in a matter of years as some have predicted, or will we overcome our problems and survive for millenia to come? If we were destroyed tomorrow, the answer to this question would be 1/100,000,000th. If we survive for 10,000 years the answer will be 1/1,000,000th.

When all of these variables are multiplied together, we arrive at: $\mathbf{N_0}$, the number of actively communicating civilizations in the galaxy.

The real value of the Drake Equation is not in finding an answer that we can say is correct, but in discussing the questions that are attached to each of the terms in the equation. Here you get a chance to be in charge of the tremendous guesswork involved in filling in the variables. As a technological and scientific society, we will learn more from astronomy, biology, and the other sciences and be able to better estimate the answers to the questions presented above.

Try the Drake Equation for Yourself:

For each of the variables in the equation, a sample number appears to assist you. In the spaces to the right of each number, enter *your own estimates* for that variable. According to the Drake Equation and with the use of a calculator, multiply your numbers and fractions to calculate N: the number of intelligent, communicating civilizations in the Milky Way galaxy.

Note: Numbers that are listed as '**f**' are written as decimal fractions. For example, 50% in the line $\mathbf{f_c}$ is entered as 0.50 into your calculator, and so on. If you arrive at an answer that is less than 1.00 (the current known value for the Drake Equation), change one or more of your estimates.

N* = Number of stars in the Milky Way galaxy.

100 billion			

$\mathbf{f_p}$ = Fraction of **N** having planetary systems.

50% = 0.50			

$\mathbf{n_e}$ = Number of planets per star capable of sustaining life.

1			

$\mathbf{f_l}$ = Fraction of $\mathbf{n_e}$ where life evolves.

30% = 0.30			

$\mathbf{f_i}$ = Fraction of $\mathbf{f_l}$ where intelligent life evolves.

20% = 0.20			

$\mathbf{f_c}$ = Fraction of $\mathbf{f_i}$ that develop the means of radio frequency communication.

10% = 0.10			

$\mathbf{f_L}$ = Fraction of a planet's natural history during which a civilization is actively communicating beyond itself into deep space.

1/1,000,000th (10,000 years)		

Calculate $\mathbf{N_0 = N^* \ f_p \ n_e \ f_l \ f_i \ f_c \ f_L}$

Example: (100,000,000,000) x (.50) x (1.00) x (.30) x (.20) x (.10) x (0.000 001)
= **N**, the number of actively communicating civilizations in the galaxy.

300			

TSM Teacher Support Material

Sample Plots of Astronomical Data for Teacher Reference, and Databases for Objects

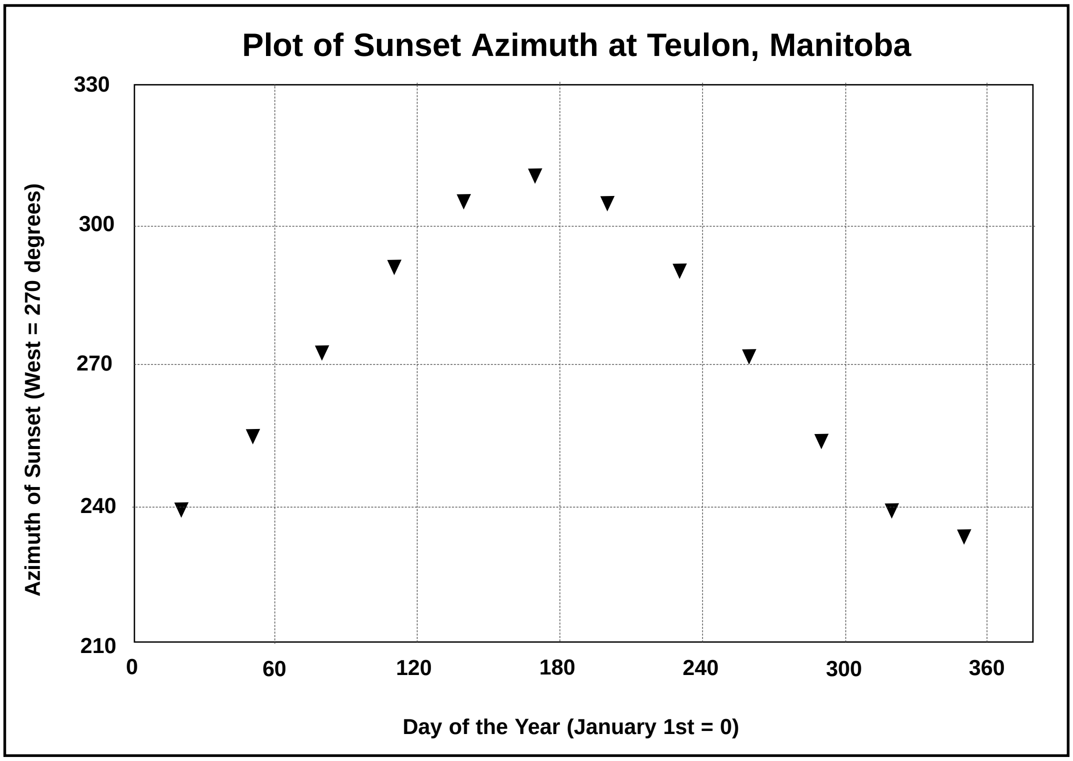
Notes for Instruction:

The following data charts are provided to supplement previously recorded data or in lieu of observational data where direct data collecting is not possible. It is preferred, however, that students acquire positioned data from astronomy software rather than use these data charts and plots. A comprehensive list of websites offering such software can be found at:

http://www.GriffithsObs.org/ or http://www.seds.org/

1. **Data Set and Plot of Sun's Azimuth at Sunset Over Time**

Day	Azimuth of Sunset
21	239.7º
51	255.1º
80	272.7º
110	291.2º
140	305.2º
170	310.7º
200	304.8º
230	290.3º
260	272.1º
290	254.2º
320	239.2º
350	233.5º



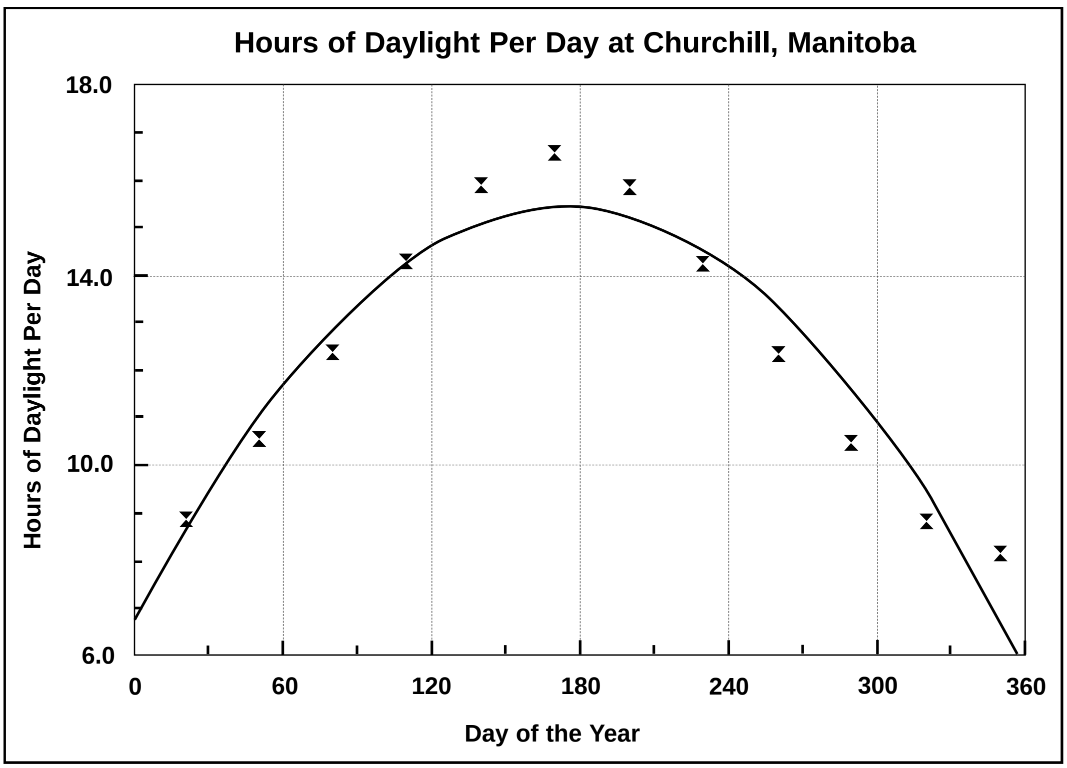
Plot of Sunset Position Over One Year at Teulon, Manitoba

The above plot illustrates that the position of sunset throughout the year follows a predictable pattern. In the winter (days 300 to 60), the Sun sets well to the southwest in the sky, corresponding with the shortest hours of daylight. As the year progresses, the Sun sets increasingly towards the north, with sunset due west (270° azimuth) at the Vernal Equinox (first day of spring). On or near the Summer Solstice of June 21st, the Sun sets at its most northerly position (day 180), going down well to the northwest on the horizon. For the remainder of the year, until the Winter Solstice of December 21st, the sunset location moves progressively southward on the horizon by about one Sun diameter per day (0.5 degree). The Earth’s axial tilt of 23.5° is responsible for this apparent motion of the Sun throughout the year.

2. **Data Set and Plot of Hours of Daylight Per Day for One Year at Churchill, Manitoba**

Day	Hours of Daylight
21	8.867
51	10.55
80	12.375
110	14.308
140	15.892
170	16.583
200	15.879
230	14.251
260	12.34
290	10.483
320	8.833
350	8.152

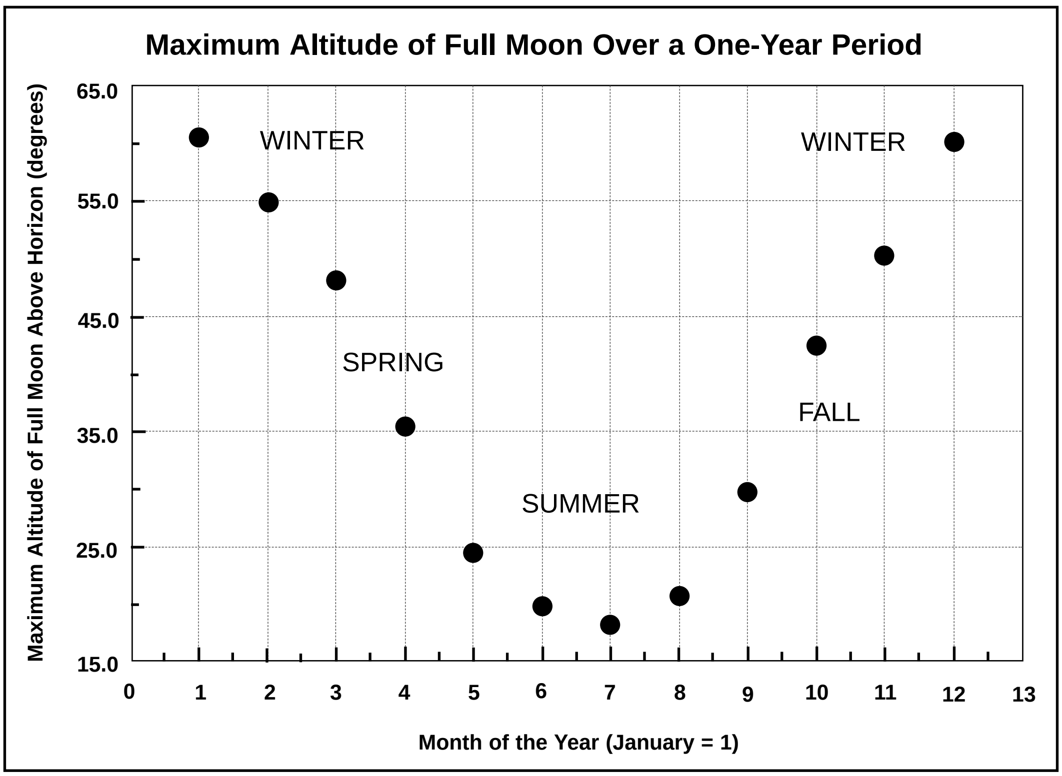
Alhough most students are aware that there are more hours of daylight in the summer than in the Manitoba winters, it is always instructive to see this represented through plotting software in graphical mode. The regularity of the increase and decrease is marked, upon closer examination, by the fact that the lengthening of daylight during the spring and the decrease in daylight in the fall are the two periods where the most rapid day-to-day changes occur (note the steepness of the plot during the intervals of spring and fall). The levelling off of the curve near the beginning of summer and winter paints not only a good numerical picture, but conjures emotions as well!



3. **Data Set and Plot of Full Moon's Maximum Altitude Over a One-Year Period**

Month of Year	Full Moon's Maximum Altitude (degrees above horizon)
Jan.	60.5°
Feb.	54.8°
Mar.	48.1°
Apr.	35.4°
May	24.4°
June	19.9°
July	18.2°
Aug.	20.8°
Sept.	29.8°
Oct.	42.4°
Nov.	50.2°
Dec.	60.1°

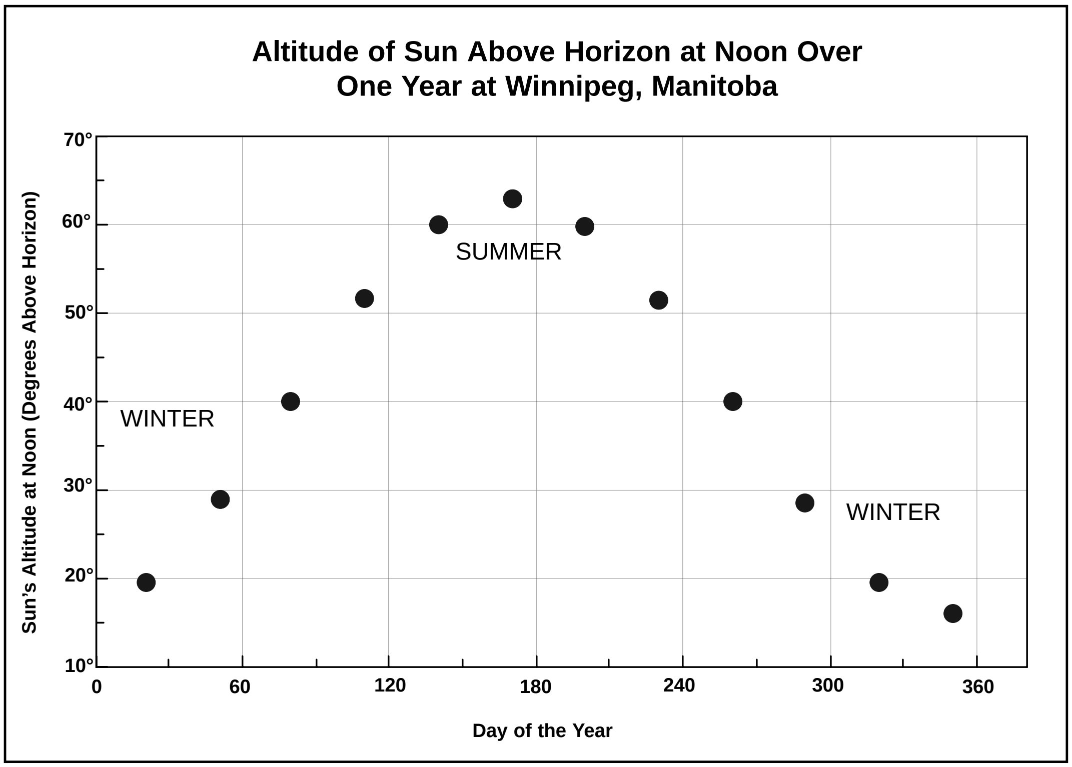
The phenomenon depicted in the graph below is generally poorly understood by the public. In the northern hemisphere, the Moon is higher in the sky during the winter and significantly lower in the sky during the summer. This results from the superposition of two geometries that are opposed to one another — the inclination of the Earth's axis with respect to its orbit around the Sun, and the inclination of the Moon's orbital path around the Earth with respect to the Equator. Historically, and for ancient cultures, it was fortuitous to have the Moon dominating the night sky at a time when the hours of daylight were shortened. One could ask the students: "Could this curious situation have an influence on the ocean tides?" In addition, it may explain why the Swampy Cree of northern Manitoba refer to the moon as "tipiskaw pissim" — or "night Sun" — as opposed to giving it a separate planetary significance.



4. **Data Set and Plot of Sun's Altitude Above the Horizon at Noon, Winnipeg Manitoba.**

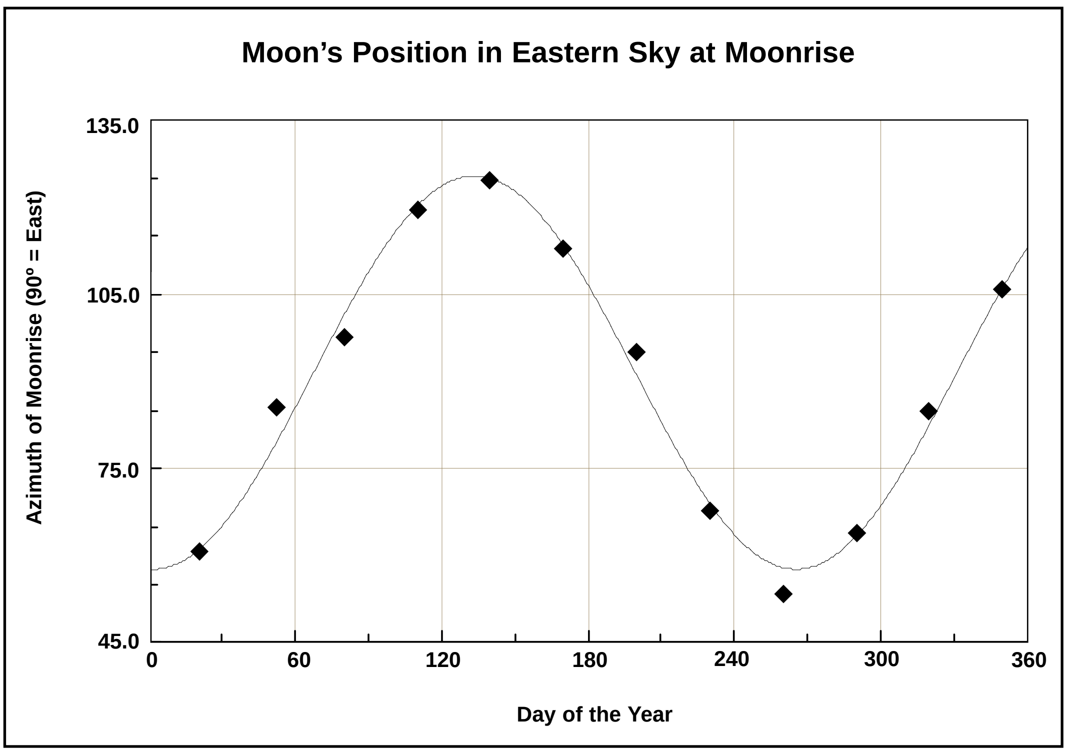
Day of Year	Altitude of Sun at Noon
21	9.7º
51	29º
80	40.2º
110	51.8º
140	60º
170	63.1º
200	60.0º
230	51.5º
260	40º
290	28.6º
320	19.6º
350	16.2º

The data required to produce the plot below could also be generated through student observation using their constructed astrolabe (as discussed previously). Determining the amplitude of the "wave" in this plot (exactly 23.5 degrees) shows that it matches the current axial tilt of the Earth.



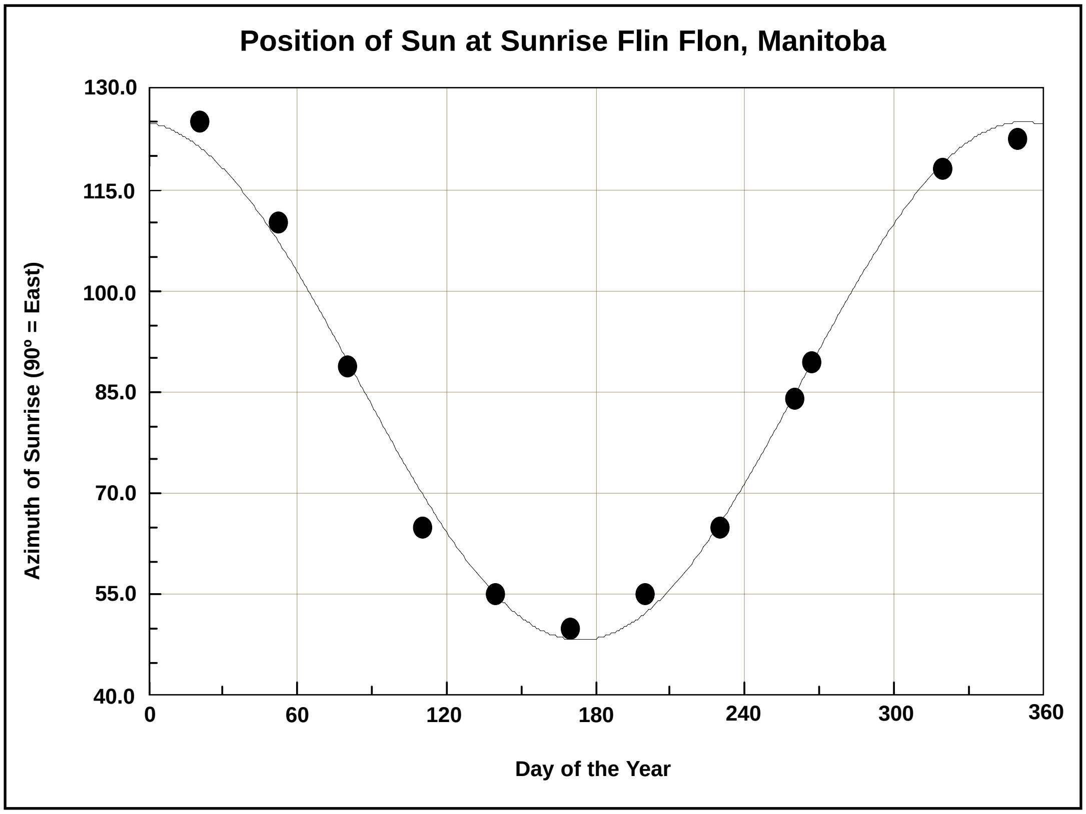
5. **Data Set and Plot of Moon's Position in the Eastern Sky at Moonrise**

Day of Year	Azimuth of Moon
21	60.7º
51	85.5º
80	97.5º
110	119.5º
140	124.7º
170	112.8º
200	95.0º
230	67.6º
260	53.5º
290	63.9º
320	84.8º
350	106.0º



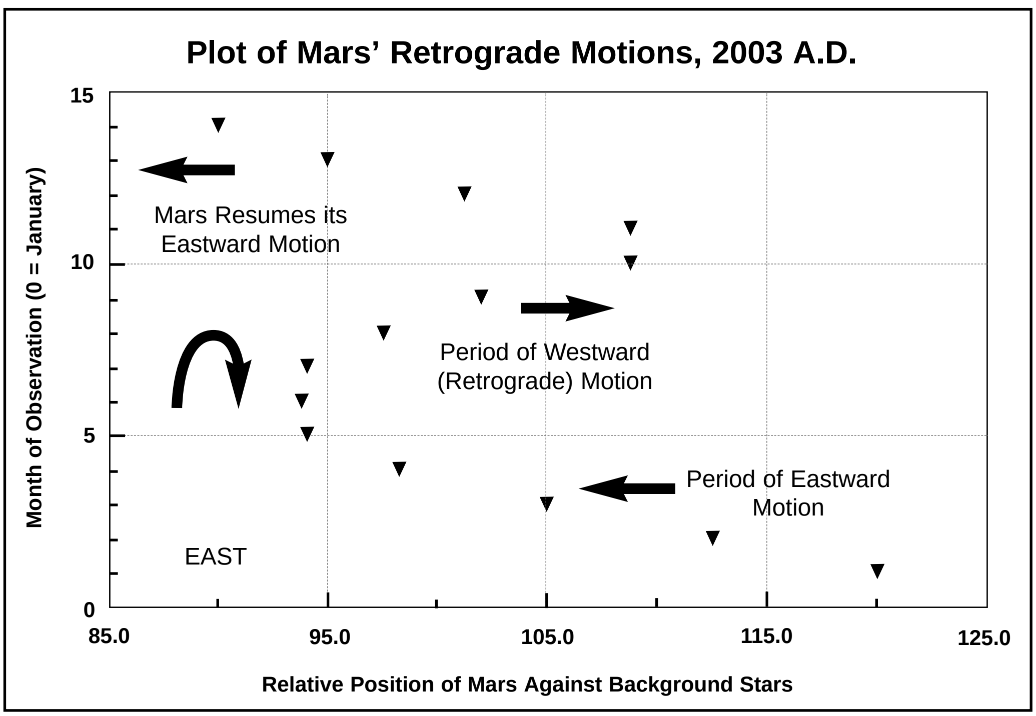
6. **Data Set and Plot of Sun's Position at Sunrise, Flin Flon, Manitoba.**

Day of Year	Azimuth of Sunrise
1	124.6º
8	125.9º
13	126.5º
20	126.5º
79	88.7º
166	49.5º
258	84.0º
267	89.5º



7. **Data Set and Plot of Mars' Retrograde Motions, 2003 A.D.**

Mars' Position	Month
120º	1 (Jan. 2003)
112.5º	2 (Feb.)
105.0º	3 (Mar.)
98.25º	4 (Apr.)
94.0º	5 (May)
93.75º	6 (June)
94.0º	7 (July)
97.5º	8 (Aug.)
102.0º	9 (Sept.)
108.75º	10 (Oct.)
108.75º	11 (Nov.)
101.25º	12 (Dec.)
95.0º	13 (Jan. 2004)
90.0º	14 (Feb. 2004)



The Great Astronomical Word Explosion

SLA Student Learning Activity

Instructions:

Complete each statement using the words and phrases below. This should be a useful review of many of the terms you have encountered in your introduction to astronomy. Some of the words can be used more than once. The numbers are used only once.

Halley	cultures and religions	minerals	white dwarf
apparent	the Earth	star	galaxies
hydrogen	Pluto	1000	Jupiter
the Sun	expansion	solar	verification
comet	nuclear fusion	instabilities	one million
suns	moons	gravity	galaxy
contraction	Alpha Centauri	light	heliocentric
Big Bang	the Milky Way	spiral	thermonuclear
supernovas	black hole	ellipse	planet
nine	150 million	one year	63,000
Hubble	aurora borealis	dispersed	light spectrum
mass	geocentric	four to five	blue
Sirius	Neptune	ray of light	asteroids
pressure	cloud of gas and dust	red	Uranus
years	10 to 15 billion years ago	neutrons	helium
radio waves	100 to 400 billion	ring	astronomical
light-year	galaxies	yellow-orange	

1. A ____________________ is a celestial body that pursues an orbit around a central ________________________. Our solar system has ______________________ of them, and some astronomers speculate that the belt of _______________________ between the orbits of Mars and Jupiter was once a tenth planet that has been destroyed.

2. It is the force of ___________________________ that holds the planets in orbit around the __________________________, and also causes the entire solar system to orbit around the ________________________________.

3. ___________________________ are natural satellites of planets. The large number of small bodies between Mars and Jupiter are called the _____________________________, which means “star-like.” Certain planets also have a _____________________________ system that encircles them, comprised of thousands of small, rocky, and icy pieces of material left over from the disintegration of a once-large satellite.

4. Certain asteroids, called the Trojans, cross the orbit of Mars and make close approaches to the Earth. Their maximum size is about ___________________________ kilometres across. Due to the fact that asteroids and moons are composed of rocky material, some people would like to exploit them as sources of _________________________________ .

5. The largest planet in the solar system is ____________________________, and the smallest is ______________________. The ‘third rocky one from the Sun’ is ___________________.

6. The four giant gas planets, listed in order of increasing distance from the Sun are _______________________, ________________________, ______________________, and _______________________ . They all have large families of _________________________ orbiting them.

7. An _____________________________________ unit (AU) is the average distance between ____________________________ and the ____________________. It is equivalent to about _____________________ kilometres. A ____________________________ is a much larger distance unit used by astronomers, and is the distance that a __________________________ traverses in ___________________________. A light-year is equivalent to about _____________________________ AU’s.

8. A _________________________ is a solar system object that can can have a gas and dust tail exceeding millions of kilometres in length. These celestial wonders of ice, rock, and organic compounds travel around the Sun in elongated orbits called an ___________________________. In 1997, Hale-Bopp was one of the most brilliant to recently enter the inner solar system, and was visible to the unaided eye for months. However, it is __________________________ that is the most celebrated __________________________, returning to put on a show with a period of about 76 years.

9. The Sun is a ______________________________, an enormous sphere of gas that emits its energy through the process of _____________________________. The temperatures in the extreme outer layer of the Sun's atmosphere, "the solar corona," can reach _____________________ degrees Celsius. Every 10 years or so, _______________________ flares erupt from the Sun's surface layers, eventually disturbing communication systems on Earth. The beautiful _______________________________ near the North Pole is caused by streams of charged particles which are emitted by the Sun and interact with the magnetic field of the Earth high in the atmosphere.

10. The nearest star to the Earth is the ____________________________. The next nearest star system to ours is __________________________, which is a triple-star system approximately _____________________________ light-years from Earth. The colour of its three stars, indicating that they are Sun-like, is ____________________________. The hottest stars are _______________________ in colour, and the coolest stars are ______________________.

11. The _________________________ magnitude (brightness as seen from the Earth) of a star differs from its absolute magnitude (a truer measure of a star's brightness) because of the great distance between the star and the Earth. This affects the quantity of ________________ that is observed in the night sky. The brightest star in the sky from our point of view is ____________________________ in the constellation *Canis Major* (the Great Dog), but it is actually much less luminous than the nearby red giant star, Betelgeuse, in the constellation Orion. Very often, stars appear bright simply because they are close to us.

12. A __________________________ is the remains of a supermassive star that is apparently invisible due to the fact that tremendous ______________________ forces do not permit its visible ______________________________ to escape and be seen.

13. Neither the _________________________ model of the universe (with the Earth at the centre) nor the ________________________ model (with the Sun at the centre) represent the actual conceptions of the cosmos accepted by astronomers today. The solar system is just one small fraction of the galaxy called ______________________________. The universe is comprised of perhaps hundreds of billions of _______________________________ like the nearest great spiral galaxy to ours, the Andromeda Galaxy.

14. A ______________________________ is actually an enormous collection of stars, dust, and various gases, all bound together by gravitational attraction. The Milky Way contains somewhere in the neighbourhood of ___________________________ stars. Some galaxies have a pinwheel-like appearance, and are called _______________________ galaxies (like the Milky Way). Still others are irregular in form (like the Large Magellanic Cloud, for instance). Quasars (which is a loose acronym for "quasi-stellar objects") are strange sources of _________________________, and can emit as much energy as an entire galaxy of stars.

15. A large cloud of gas and dust called a ______________________________ is often called the "birthplace of stars." These clouds of gases, mostly _______________________________ and ________________________, contract under the influence of __________________________. A star is born when its ______________________________ furnace inside ignites as temperatures rise to millions of degrees Celsius.

16. Depending on the initial _____________________ of the material from the nebula that coalesces to form a star, the resulting star can end its life span as a small ___________________________, or as a spectacular ______________________ explosion that leaves behind a super-dense remnant called a ______________________ star. The most massive stars, those about 25 times heavier than our Sun, have the potential to become a ____________________________, from which time and space cannot escape. All of the chemical elements that make up other stars, planets, and matter (including living beings like you) are synthesized from the exploding stars.

17. By analyzing the rainbow-like colours of a _____________________ from a celestial body (for example, a star beyond our Sun), it is possible to detect planets around it by looking for small _____________________ in the motions of the central star. The ____________________ Space Telescope has already confirmed the existence of a number of planetary systems around stars other than our Sun.

18. According to cosmologists (scientists studying the ultimate fate of the cosmos), it is thought that after the universe's initial period of _________________________, a period of ___________________________ will result in what has been called "the Big Crunch." After that, another ______________________________ could give rise to a whole new universe.

19. The ______________________________ Theory also proposes that all of the material that now comprises the universe was originally concentrated in an exceedingly small volume of space — infinitely small. This mass was under great _______________________, and upon exploding rapidly outward, _______________________ the enormous mass of material that ultimately gave rise to stars, galaxies, and a host of other celestial objects.

20. A diversity of peoples, __________________________________ have proposed their own particular explanation for the origins of the universe, but these perspectives have not utilized the methods and habits of mind traditionally used in the scientific _______________________ of ideas.

TSM Teacher Support Material

The Great Astronomical Word Explosion (Teacher Version with Answers)

Instructions:

Complete each statement using the words and phrases below. This should be a useful review of many of the terms you have encountered in your introduction to astronomy. Some of the words can be used more than once. The numbers are used only once.

Halley	cultures and religions	minerals	white dwarf
apparent	the Earth	star	galaxies
hydrogen	Pluto	1000	Jupiter
the Sun	expansion	solar	verification
comet	nuclear fusion	instabilities	one million
suns	moons	gravity	galaxy
contraction	Alpha Centauri	light	heliocentric
Big Bang	the Milky Way	spiral	thermonuclear
supernovas	black hole	ellipse	planet
nine	150 million	one year	63,000
Hubble	aurora borealis	dispersed	light spectrum
mass	geocentric	four to five	blue
Sirius	Neptune	ray of light	asteroids
pressure	cloud of gas and dust	red	Uranus
years	10 to 15 billion years ago	neutrons	helium
radio waves	100 to 400 billion	ring	astronomical
light-year	galaxies	yellow-orange	

1. A _____*planet*_____ is a celestial body that pursues an orbit around a central _____*star*_____. Our solar system has _____*nine*_____ of them, and some astronomers speculate that the belt of _____*asteroids*_____ between the orbits of Mars and Jupiter was once a tenth planet that has been destroyed.

2. It is the force of _____*gravity*_____ that holds the planets in orbit around the _____*Sun*_____, and also causes the entire solar system to orbit around the _____*Milky Way*_____.

3. _____*Moons*_____ are natural satellites of planets. The large number of small bodies between Mars and Jupiter are called the _____*asteroids*_____, which means "star-like." Certain planets also have a _____*ring*_____ system that encircles them, comprised of thousands of small, rocky, and icy pieces of material left

over from the disintegration of a once-large satellite.

4. Certain asteroids, called the Trojans, cross the orbit of Mars and make close approaches to the Earth. Their maximum size is about ___*1,000*___ kilometres across. Due to the fact that asteroids and moons are composed of rocky material, some people would like to exploit them as sources of ___*minerals*___.

5. The largest planet in the solar system is ___*Jupiter*___, and the smallest is ___*Pluto*___. The 'third rocky one from the Sun' is ___*Earth*___.

6. The four giant gas planets, listed in order of increasing distance from the Sun are ___*Jupiter*___, ___*Saturn*___, ___*Uranus*___, and ___*Neptune*___. They all have large families of ___*moons*___ orbiting them.

7. An ___*astronomical*___ unit (AU) is the average distance between ___*Earth*___ and the ___*Sun*___. It is equivalent to about ___*150 million*___ kilometres. A ___*light-year*___ is a much larger distance unit used by astronomers, and is the distance that a ___*ray of light*___ traverses in ___*one year*___. A light-year is equivalent to about ___*63,000*___ AU's.

8. A ___*comet*___ is a solar system object that can can have a gas and dust tail exceeding millions of kilometres in length. These celestial wonders of ice, rock, and organic compounds travel around the Sun in elongated orbits called an ___*ellipse*___. In 1997, Hale-Bopp was one of the most brilliant to recently enter the inner solar system, and was visible to the unaided eye for months. However, it is ___*Halley*___ that is the most celebrated ___*comet*___, returning to put on a show with a period of about 76 years.

9. The Sun is a ______*star*______, an enormous sphere of gas that emits its energy through the process of ______*nuclear fusion*______. The temperatures in the extreme outer layer of the Sun's atmosphere, "the solar corona," can reach ______*one million*______ degrees Celsius. Every 10 years or so, ______*solar*______ flares erupt from the Sun's surface layers, eventually disturbing communication systems on Earth. The beautiful ______*aurora borealis*______ near the North Pole is caused by streams of charged particles which are emitted by the Sun and interact with the magnetic field of the Earth high in the atmosphere.

10. The nearest star to the Earth is the ______*Sun*______. The next nearest star system to ours is ______*Alpha Centauri*______, which is a triple-star system approximately ______*four to five*______ light-years from Earth. The colour of its three stars, indicating that they are Sun-like, is ______*yellow-orange*______. The hottest stars are ______*blue*______ in colour, and the coolest stars are ______*red*______.

11. The ______*apparent*______ magnitude (brightness as seen from the Earth) of a star differs from its absolute magnitude (a truer measure of a star's brightness) because of the great distance between the star and the Earth. This affects the quantity of ______*light*______ that is observed in the night sky. The brightest star in the sky from our point of view is ______*Sirius ("serious")*______ in the constellation *Canis Major* (the Great Dog), but it is actually much less luminous than the nearby red giant star, Betelgeuse, in the constellation Orion. Very often, stars appear bright simply because they are close to us.

12. A ______*black hole*______ is the remains of a supermassive star that is apparently invisible due to the fact that tremendous ______*gravitational*______ forces do not permit its visible ______*light*______ to escape and be seen.

13. Neither the ______*geocentric*______ model of the universe (with the Earth at the centre) nor the ______*heliocentric*______ model (with the Sun at the centre) represent the actual conceptions of the cosmos accepted by astronomers today. The solar system is just one small fraction of the galaxy called ______*the Milky Way*______. The universe is comprised of perhaps hundreds of billions of ______*galaxies*______ like the nearest great spiral galaxy to ours, the Andromeda Galaxy.

14. A ___*galaxy*___ is actually an enormous collection of stars, dust, and various gases, all bound together by gravitational attraction. The Milky Way contains somewhere in the neighbourhood of ___*100 to 400 billion*___ stars. Some galaxies have a pinwheel-like appearance, and are called ___*spiral*___ galaxies (like the Milky Way). Still others are irregular in form (like the Large Magellanic Cloud, for instance). Quasars (which is a loose acronym for "quasi-stellar objects") are strange sources of ___*radio waves*___, and can emit as much energy as an entire galaxy of stars.

15. A large cloud of gas and dust called a ___*nebula*___ is often called the "birthplace of stars." These clouds of gases, mostly ___*hydrogen*___ and ___*helium*___, contract under the influence of ___*gravity*___. A star is born when its ___*thermonuclear*___ furnace inside ignites as temperatures rise to millions of degrees Celsius.

16. Depending on the initial ___*mass*___ of the material from the nebula that coalesces to form a star, the resulting star can end its life span as a small ___*white dwarf*___, or as a spectacular ___*supernova*___ explosion that leaves behind a super-dense remnant called a ___*neutron*___ star. The most massive stars, those about 25 times heavier than our Sun, have the potential to become a ___*black hole*___, from which time and space cannot escape. All of the chemical elements that make up other stars, planets, and matter (including living beings like you) are synthesized from the exploding stars.

17. By analyzing the rainbow-like colours of a ___*light spectrum*___ from a celestial body (for example, a star beyond our Sun), it is possible to detect planets around it by looking for small ___*instabilities*___ in the motions of the central star. The ___*Hubble*___ Space Telescope has already confirmed the existence of a number of planetary systems around stars other than our Sun.

18. According to cosmologists (scientists studying the ultimate fate of the cosmos), it is thought that after the universe's initial period of ___*expansion*___, a period of ___*contraction*___ will result in what has been called "the Big Crunch." After that, another ___*expansion*___ could give rise to a whole new universe.

19. The ____________*Big Bang*____________ Theory also proposes that all of the material that now comprises the universe was originally concentrated in an exceedingly small volume of space — infinitely small. This mass was under great _________*pressure*__________, and upon exploding rapidly outward, _________*dispersed*__________ the enormous mass of material that ultimately gave rise to stars, galaxies, and a host of other celestial objects.

20. A diversity of peoples, ______*cultures and religions*_________ have proposed their own particular explanation for the origins of the universe, but these perspectives have not utilized the methods and habits of mind traditionally used in the scientific ______*verification*_______ of ideas.

SLA
Student Learning Activity

Weighing the Benefits and Risks of Space Exploration

Indicate if you agree or disagree with each statement. If your opinion is mixed, explain why. You will be asked to discuss each of these points with the class when finished.

Statement	I Agree	I Disagree	Mixed Opinion
It is absolutely necessary to do all we can to contact extraterrestrial intelligences in order to secure the benefits of their advanced technologies.			
The discovery and exploitation of mineral resources on asteroids is more important in the long term than our health care system is in the short term.			
It is wise to use nuclear-powered engines for space travel since these permit us to travel much farther at a reduced price.			
If we do not survey the heavens with more complex instruments, we will not be in a position to defend the Earth against dangerous events like asteroid impacts.			
Space belongs to those countries and commercial interests that colonize and exploit it economically.			
Attempts at the colonization of space should respect the current ethnic proportions and balance of women and men that exist here on Earth.			
Remote sensing observation will be an essential tool in determining “who we take,” “what we take,” and “where we go” when we colonize the solar system.			
If we were to “terraform” Mars, another planet, or a moon in the solar system, it would be necessary to understand all of the impacts that human colonization would have on the “new home.”			
The Canadian government should reduce its expenditures on non-essential space research and concentrate its efforts in improving agricultural productivity on Earth.			
The primary role of space agencies is to ensure that one's nation is capable of defending against a military attack from space-based weapons.			
It is not a problem that space tourism will only be affordable by the rich. This should be encouraged until access is available for all potential tourists.			
It is impossible to pollute space, therefore, it would be a good place to send our wastes and our undesirable or dangerous organisms.			

Canadian Projects in the Space Sciences

SLA Student Learning Activity

Research three scientific projects or new technologies that affect Canadian efforts in space exploration. Identify and summarize the key results in the chart below. Be prepared to discuss your research with the class.

Key Result Areas	Project 1	Project 2	Project 3
Name of Canadian project or new technology			
Brief description of the project or new technology			
Does the project or new technology involve international cooperation? If yes, with which nation(s)?			
What are the positive results of Canada's participation in this project or development of this new technology? When will these results occur?			
What are some of the concerns or worries that surround this project or new technology?			
Identify one or two of your information sources related to the advantages of the project or new technology.			