Appendix 1: Overview of Planetarium Program Concepts

Moravian College Astronomy—EASC-130:
Astronomy Labs: Working Document-Planetarium Programs

1. **INTRO. TO THE PLANETARIUM ENVIRONMENT**
   a. **Students face south in the planetarium which is set for the date**
   b. **Celestial Sphere: Ancient Greek concept where the sky was considered to be like an overhead dome with the stars "thumb-tacked" onto it.**
   c. **Sunset: Demonstrate a planetarium sunset.**
   d. **Cardinal points: The four directions. Ways of remembering them is as follows:**
      1) **(NEWS): North-East-West-South**
      2) **North never Eats Soggy Waffles if facing north and rotating clockwise through east, south, and finally west. N=0º, E=90º, S=180º, W=270º, N=360º or 0º.**
      3) **WE: Face north and stretch out your arms to either side. Spell the word "WE." The letter to the left is west, while the letter to the right is east.**
   e. **Locate planets currently visible in the sky before working with annual motion.**
   f. **Meridian: Great circle intersects south, zenith, NCP, north**
   g. **Vertical Circle: Any great sky circle which intersects the zenith and the horizons at a 90º angle (redundancy here).**
   h. **Time: Hour angle of sun from meridian +/- 12, gives local apparent solar time using a 24-hour clock. Clock time is actually created by monitoring a fictitious sun moving uniformly along the celestial equator.**
      1) **Ante Meridiem (Latin): before the meridian—midday, before noon, AM**
      2) **Post Meridiem (Latin): after midday the meridian, after the noon, PM**
      3) **Using a 24-hour clock, use 12:00 for noon for and 24:00 for midnight.**

4) **There are no international standards established for the meaning of 12 a.m. and 12 p.m. although saying 12 noon and 12 midnight does not create any confusion in understanding.**

   <u>The American Heritage Dictionary of the English Language</u> has a usage note on this topic: "By convention, ***12 AM*** denotes midnight and ***12 PM*** denotes noon. Because of the potential for confusion, it is advisable to use ***12 noon*** and ***12 midnight***." This definition will not be accepted in class. Because there is no agreement insurance policies almost never end at midnight or noon, but rather 12:01 a.m.

i. **<u>Rotation</u>: Spinning—23 hours 56 min 4 sec. Gives us day and night**
   1) **<u>Demonstrate rotation</u> in the planetarium.**
   2) **<u>Students stand up and rotate counterclockwise-right to left</u>: Notice that the direction of your rotation is opposite to the way the room is spinning.**
   3) **<u>The Earth rotates from west to east</u>** objects rise in the east and set in the west.
   4) **<u>When the sun is visible, it is daytime</u> in the planetarium.**
   5) **<u>The angle of rising and setting</u> of objects is equal to 90º – your latitude position.**
      a) **<u>Rotation at equator</u>: Objects rise straight up and set straight down. Note the number of constellations visible.**
      b) **<u>40º North</u>: Objects rise and set at an angle of 50º. Constellations visible…**
      c) **<u>North Pole</u>: Objects do not rise and set. It is like being on a merry-go-round. Constellations visible…**
   6) **<u>23 hours, 56 minutes</u>: Why we don't keep time by the stars which would equal one Earth rotation:**
      a) **<u>Sun/star on meridian</u>: Rotate Earth in one sidereal day increment of 23 hr. 56 min. Watch what happens to the sun and the star. The star returns to the meridian, but the sun ends the period eastward by one degree due to the Earth's**

revolution around the sun. It takes four extra minutes of Earth rotation to bring the sun back to the meridian, hence creating the difference between the sidereal and (apparent) solar day.

b) Star on meridian: Rotate Earth in increments of 23 hours 56 minutes and watch what happens to the sun.

7) A 24 hour (clock) day: Sun on meridian and rotate Earth in increments of 24 hours.

a) The clock day is a direct function of the rotation of the Earth and the 4 minutes necessary to bring the sun back onto the meridian. What happens to the stars and why?

b) Equation of time: describes the discrepancy between *apparent solar time* and *mean solar time*, which tracks a fictitious "mean or sun or a sun with a uniform motion" with noons exactly 24 hours apart. EoT = ApparentST-MeanST

c) Computer Simulation only—EOT = 0 for August 31: Run annual motion forward by 24-hour increments to see how the apparent sun runs ahead of or behind the ficticous sun.

j. Revolution: Earth orbits the sun in 365.24 days. This is known as the Tropical Year. Its reference position is the vernal equinox not a star. This will always keep repetitive events such as Christmas occurring during the same season of the year. The vernal equinox moves westward among the stars due to the precession of the equinoxes (25,800 years)

1) The revolution of the Earth is responsible for the seasonal changes of the constellations.

2) Stars stay fixed with respect to one another, but the planets, sun, and moon move counterclockwise, towards the east against the celestial sphere as they (including Earth) orbit counterclockwise around the sun.

3) **For each 24-hour day, the Earth revolves about one degree in its orbit around the sun moving the sun about one degree to the east. We add an extra four minutes to the sidereal day bringing the sun back to the meridian which also causes new stars to appear in the east and other stars to set in the west.**
4) **This motion over the period of weeks and months creates the seasonal changes in the constellations.**
5) **There is always one more sidereal day in a calendar year, 366 solar day/367 sidereal days in a year/leap year.**

k. **Altitude and Azimuth:**

1) **Azimuth: An angular measurement made along the horizon, starting at north which equals zero and proceeding eastward to the verticle circle which contains the object.**
2) **Altitude: An angular measurement made from the horizon along the verticle circle which contains the object, to the object.**
3) **Verticle Circle: Any great circle centered on the Earth's center which intersects the zenith. By this definition, it must also intersect the horizons opposite to each other at a 90º angle.**

l. **Equatorial Coordinate System: It is the projection of the latitude and longitude into space (Geocentric Earth)**

1) **Celestial Equator: It is the projection of the terrestrial equator into space. (use a Geocentric Earth of one is available.)**
2) **Right Ascension: Angular distance measured eastward from the vernal equinox to the circle of declination which contains the object. Measured as a unit time starting at the Vernal Equinox which equals zero hours. Think of it as longitude, but it only measures eastward from the vernal equinox.**

3) <u>Declination</u>: Angular measurement made northward or southward from the celestial equator along the circle of declination which contains the object, to the object.

a) <u>North of the Celestial Equator</u>: Declination is positive and is noted with a (+).

b) <u>South of the Celestial Equator</u>: Declination is noted as negative and is noted with a (-).

4) <u>Vernal Equinox</u>: The point of intersection where the celestial equator crosses the ecliptic at the ascending node.

m. <u>Ecliptic</u>: Earth's orbital plane projected into space/path of the sun against the stars due to Earth's revolution.

1) <u>Earth's axial tilt determines the variation in the sun's path</u> with respect to its terrestrial and celestial equators.

2) <u>Twelve zodiacal constellations</u> were given great importance by ancient civilization with respect to astrology. These 12-star patterns lay along the sun's yearly path as Earth revolved around the sun.

n. <u>Planets, Sun, and Moon move towards the East</u> (audience looking south): Run annual motion forward to show that solar system objects move eastward in the sky.

1) <u>Eastward motion</u> is called <u>direct or prograde</u>.

2) <u>Westward motion</u> is called <u>retrograde</u> or is noted as a <u>regression</u>. Precession is also a (westward) regression of the nodal point of the vernal equinox. A node is a crossing point.

o. <u>Why is Polaris stationary</u>?

1) <u>Circular motion of the stars</u> around the North Celestial Pole (NCP) and South Celestial Pole (SCP) created by the projection of Earth's axis into space and made visible by Earth's rotation. The North Star just happens to be close, less than one degree—currently (2018) just under 43 minutes of arc from the North Celestial Pole.

2) <u>Demonstration of Stationary NCP</u>: Each student finds his or her unique NCP overhead, then slowly rotates.

Stars should appear to circle around their unique North Star.

3) **Polaris not the brightest star of the night: It is the 48th brightest star in the sky when the sun is included as number one.**

p. **Precession of the equinoxes (General Precession):**

1) **Use a bicycle wheel to demonstrate precession of Earth's axis. It is caused by a differential gravitational tug on the sunward equatorial bulge of Earth. In other words, the sun is trying to pull the Earth's equator into the plane of the ecliptic, but since the Earth is rotating, the action of the downward vector acts at a right angle to this force causing the Earth's axis to precess or wobble.**
2) **Time for one cycle is 25,800 years: 26,000 years is good enough.**
3) **Thuban was the North Star in 2600 BC when the Great Pyramid was constructed: Precess the Earth's axis backwards to the time when the Great Pyramid at Giza was constructed (2,470 BC) to show that different objects were visible in the heavens, such as the Southern Cross and Alpha Centauri.**
4) **Precession affects the rising and setting positions of stars, but not the positions of the stars to one another:** Over short periods of time such as 5-10 thousand years the star patterns in the sky do not change.
5) **Vega as the North Star: Precess the Earth forward to 14,000 AD when Vega will by our North Star.**
6) **Rising and setting positions of planets have remained the same because the Earth's axial tilt has been (essentially) the same. The ecliptic remains in the same position with respect to the celestial equator and the horizons as it was thousands of years ago keeping the planets, sun, and moon rising and setting in the same positions.**

2. SEASONAL EFFECTS

a. <u>Direct and Indirect insolation</u> classroom demonstration**:**

1) <u>Punches</u>: Make the analogy of direct and indirect punches in a fight.

2) <u>Flashlight shining on a white board</u> illustrates the effect of the sun's altitude and the amount of energy received at the surface of the Earth at different angles. Draw a circle around boundary of the beam of light when it is shining directly as opposed to indirectly.

3) "<u>Megalite</u>": A person wearing a dark-colored shirt is blindfolded, and a high intensity beam of white light is focused directly and indirectly on that individual. The effects of heat absorbtion are easy to detect.

b. <u>Globe and ruler demonstrations</u> in the classroom:

1) <u>Identify the following</u>: ecliptic, perpendicular to the ecliptic, axis, rotation, local latitude (position), zenith, north and south horizons.

2) <u>Axial Tilt and Insolation</u>: Show how the 23.5 degree Earth's axial tilt of the Earth to the perpendicular of its axis and Earth's revolution affects the amount of insolation received in the Lehigh Valley.

c. <u>A Private Universe classroom</u>: Run the short introductory clip to highlight how pervasive the misconception is with regards to how individuals relate distance to seasons (closer-hotter/farther-cooler).

d. <u>Ecliptic/Celestial Equator</u>: Emphasize 23.5^o inclination of celestial equator to ecliptic.

1) <u>Identify the Vernal and the Autumnal Equinox</u> points in sky, where the celestial equator and ecliptic intersect.

2) <u>Ecliptic/Celestial Equator Intersections:</u> These represent the midpoints of the sun's annual path due to Earth's revolution.

a) <u>Vernal Equinox</u>: Ascending node… Sun crosses the celestial equator moving northward. It is the origin of the equatorial coordinate system (RA and Dec).

b) <u>The Tropical Year</u> represents the time interval between two crossings of the vernal equinox. This keeps the calendar in synch with holidays, but slowly changes the nighttime constellations at the time of the year when these occur. As an example, in 13,000 years we will be still celebrate Christmas on December 25 and it will be wintertime, but our present-day summer constellations will be in the sky.

c) <u>Autumnal Equinox</u>: Descending node… Sun crosses the celestial equator moving from north to south.

d) <u>Angle of intersection of the ecliptic and celestial equator is always equal to the axial tilt</u> of the Earth, approximately 23.5 degrees.

e) <u>Maximum deviation of the ecliptic from the celestial equator</u> always equals the inclination of the Earth's axis from the perpendicular to the ecliptic.

f) <u>Vernal and Autumnal equinoxes are not stationary</u>. They slowly move because of the precession of the equinoxes.

3) <u>In a spherical coordinate system, the angle of intersection</u> of the two planes as well as the maximum deviation of the planes from each other is always the same. The position of maximum angular deviation from the celestial equator corresponds to the solstice (sun standstill) positions.

a) <u>Summer solstice</u>: Maximum deviation above the celestial equator (most likely date, June 21).

b) <u>Winter solstice</u>: Maximum deviation below the celestial equator (most likely date, December 21).

c) <u>Equinoxes</u>: Sun is crossing celestial equator at its maximum northward or southward motion.

1)) Vernal Equinox: Occurs usually on the 19th or 20th of March.

2)) Autumnal Equinox: Usually occurs on the 22nd or 23rd of September.

4) **<u>Tropical Year/Vernal Equinox</u>: 365.24 days… <u>It is not the sidereal year</u> that we measure via our calendars which is 365.26 days.**
5) **<u>Because the year is based on a seasonal indicators,</u> the calendar always stays in step with the seasons.**
   a) **<u>Remember the Julian Calendar</u>, in which Christmas is approaching Easter. In the Julian calendar Christmas currently occurs on Jan. 7 with respect to the Gregorian calendar.**
   b) **This is happening because Easter is based upon a seasonal indicator (vernal equinox), while the Julian calendar is not.**

e. **<u>Seasonal effects for the following latitudes are demonstrated</u>:**
   1) **<u>40º N</u> (local position): Note the three major effects of the seasons: These are monitored by running daily and annual motion concurrently to keep the sun stationary on the meridian (noon position). Can do this at Kutztown if the sun is on the meridian and 24-hour increments are inputted. While this is occurring, the ecliptic and celestial coordinates are visible. Students are to note the following:**
      a) **<u>Change in rising and setting positions of the sun</u>: Change in rising and setting azimuths of the sun.**
      b) **<u>Change in the altitude of the sun</u> is measured on meridian.**
      c) **<u>Change in the length of the day</u>: Count the number hours that the sun is visible using the hour angles of the equatorial coordinates passing the meridian.**
      d) **<u>Plant the corn or die exercise</u>** (After archaeoastronomy introduction)**: A student is chosen as an Ancestral Puebloan priest to monitor the sun's daily rising positions along the eastern horizon. After observing a full year's worth of sunrises, the student priest will pick a position**

where he/she thinks it is safe to planet the corn (beyond the last killing frost).

2) <u>66.5º N</u>: (Arctic Circle)

a) <u>Summer solstice</u>: June 21. It is the time of the midnight sun. Sun technically does not set.

b) <u>Winter solstice</u>: December 21. Sun does not technically rise. Note that it does get light in the south for several hours surrounding noontime.

3) <u>90º N</u>, (North Pole): Sun is up or down for six months at a stretch.

a) <u>Sun spirals up and down</u> as Earth rotates/revolves, rising (approximately March 21) and setting (approximately September 21) on the equinox dates.

b) <u>After sunset, darkness takes about six weeks to become fully effective</u>: By that time the sun is 18º below the horizon (declination of the sun is -18º).

c) Even though poles are considered cold deserts, there are <u>long stretches of cloudy weather</u>. This occurs for higher latitudes as well. Winters can often have periods which are overcast for many days.

4) <u>23.5º N</u>: (Tropic of Cancer). Because the population of the Northern Hemisphere is much greater than the Southern Hemisphere, more people die of cancer in the NH than in the SH. It is a macabre way of remembering which tropic line is north of the equator.

a) The Topic of Cancer is not just a circle "painted" on the Earth's surface. It is the <u>Northern limit for the zenithal sun on summer solstice</u>:

b) <u>Directly related to Earth's axial tilt</u>. This can be compared to other planets to see where their topic circles would lie based upon their axial tilts.

c) <u>Occurs about June 21</u> on average.

5) <u>0º</u>: (Equator)

a) <u>Sun zigzags between Northern and Southern</u> Hemispheric limits over the duration of a year.

b) Sun is at the zenith (90º) on the equinox dates.
c) Low sun (66.5º N/S) occurs on the solstice dates.
d) Stars rise and set perpendicular to horizon. Shortest interval of twilight on Earth is recorded here. People traveling to tropical locales are usually surprised at how rapidly it becomes dark after sunset.

6) 23.5º S: (Tropic of Capricorn)
a) Southern limit for zenithal sun: 23.5º S. Latitude.
b) Occurs on the summer solstice for the Southern Hemisphere, about December 21.

7) Students take data for graphical exercise on the seasons that they will complete as a homework exercise. This data will include the sun's altitude on the solstices and equinoxes, as well as a month before and after these times.

3. PHASES OF THE MOON: (Show phases in the planetarium around the equinoxes). Remember the "Moon on a Stick" exercise in which we detailed the eight main lunar phases. Students complete the "Rhythm of the Moon Exercise" in their books (Planetarium exercise)

a. New: rises and sets with the sun
b. First Quarter: rises noon, sets midnight
c. Full Moon: rises at sunset, sets at sunrise--just the opposite of the sun and the new moon. Moon is at opposition.
d. Last Quarter/Third Quarter: rises at midnight, sets at noon
e. Waning and waxing crescent/gibbous phases will be demonstrated in the planetarium.

4. ALTITUDE AND AZIMUTH: A local coordinate system which is time dependent and unique for each observer.

a. Azimuth: angle measured eastward from the north point along the horizon to the vertical circle which contains the object.

b. <u>Altitude</u>: angle measured from the horizon along the vertical circle which contains the object, to the object.
c. <u>Time creates uniqueness</u> to the system because the Earth is rotating and this must be taken into consideration when noting a position in altitude and azimuth.
d. <u>Navigation</u>: Because the altitude and azimuth of an object are unique for only one position on the surface of the Earth at one specific moment in time, it is possible to use this uniqueness to work a problem backwards to find one's unknown location on the surface of the Earth. The measurements of the altitude of three stars with known equatorial coordinate positions are used to calculate an unknown location on the Earth. The time at some known longitude position must also be known.
e. <u>Celestial Navigation Lab</u> will possibly follow at a later date.

5. <u>LATITUDE AND LONGITUDE</u>: (Use transparent sphere)
a. <u>Longitude</u>: The angle measured from the Earth's center along the equator, east or west from the Prime Meridian to the vertical circle which contains the place.
b. <u>Latitude</u>: The angle measured from the Earth's center, north or south from the equator along the vertical circle which contains the object, to the position of the place.
c. <u>Must specify hemispheric locations, N/S for latitude and E/W for longitude</u> because no position on Earth is unique without it.
d. <u>International Date Line</u>: It is the east/west boundary for the rectification of the day, approximately located at 180º longitude. It is used to rectify the westward-earlier/eastward-later problem associated with time.

6. <u>EQUATORIAL COORDINATE SYSTEM</u>: This is the coordinate system used by astronomers for locating objects on the celestial sphere.
a. It is a <u>Projection of Latitude and Longitude</u> into space.

b. **The Origin position is located at the Vernal equinox, the intersection point or the ascending node of the ecliptic with the celestial equator. When the sun crosses this position, it is the first moment of spring. At this time the sun moves from below the celestial equator to a position above the celestial equator.**
c. **Right Ascension is to longitude as Declination is to latitude.**
   1) **Right Ascension (RA) is measured as an increment of time, with hours, minutes, and seconds. These increments of time are slightly shorter than the time which our wall clocks keep (mean solar time).**
   2) **The time Component is a function of the rotation of the Earth, with one complete rotation equal to a sidereal day, 23 hours, 56 minutes, 4 seconds.**
   3) **RA always increases eastward from the Vernal Equinox from 0 to 24 hours. There is no International Date Line in right ascension or the sky.**
   4) **Sidereal Day: The entire system of RA makes one complete circuit of the heavens in one Earth rotation—23 hours, 56 minutes.**
   5) **Local Sidereal Time: The circle of RA transiting a local meridian equals the sidereal time or star time.**
   6) **Equatorially mounted telescopes: Telescopes which have their polar axis pointed towards the North Celestial Pole, the position where the Earth's axis intersects the sky, will be able to use the equatorial coordinate system to allow an astronomer to find any celestial object in the sky.**
      a) **The difference in sidereal time between the meridian and the object and the difference in declination between where the telescope is pointed and the declination of the object allow the observer to offset the telescope by the correct angle to find the desired object.**

b) The angular difference in RA and Dec. between any two celestial objects will allow an astronomer to slew from one object to another.

c) For several decades, internal encoders and computers have taken the burden of these calculations away from the observer through GOTO and "push to" mounting systems. We have both systems at Moravian College, but the GOTO system will be our priority.

d. Declination is to latitude as Right Ascension is to longitude.

1) Measured as a + (positive-north) or – (negative-south) angle from the celestial equator which equals 0.

2) Maximum declination N/S is +90º and -90º.

7. LUNAR STANDSTILL POSITIONS: (Archaeoastronomy) Extreme positions of the moon.

a. Extreme positions of the moon are caused by the 5º inclination of the moon's orbit to the plane of the ecliptic.

b. Lunar standstills occur when the position of the moon lies at their maximum deviations above and below the solstice points. They were considered important to ancient cultures that monitored the sky.

c. Created by the regression of the moon's nodes:

1) Node: A crossing point where two planes intersect. In this instance it is the moon's orbit and the ecliptic which intersect. Another node is the vernal or autumnal equinoxes where the ecliptic and celestial equators cross.

2) Cause: Precession of the moon's orbit is created by the sun's differential gravity attempting to pull the moon's orbit into the plane of the ecliptic. The action of this force is at right angles to the applied force, because the moon is in orbital motion (revolution) around the Earth. This causes the moon's nodes to regress towards the west. It is similar to the wobble of a spinning top and

the 26,000-year westward precession of the Earth's vernal equinox.

3) **The moon's regression cycle takes 18.61 years.**
4) **<u>Demonstrate</u> how the 5º inclination of the moon's orbit, coupled with the moon's nodical regression, creates these extremes.**
5) **<u>The moon's specific phase</u> with respect to its position in the sky (RA and Dec.), repeats itself once every 18.61 years.**

8. **<u>MAJOR STANDSTILL POSITIONS</u>: Extreme locations of the moon in north and south declination +/- 28.5 degrees. They are +23.5º + 5º or -23.5º - 5º created by the maximum deviation of the ecliptic from the celestial equator (solstice positions) coupled with the maximum lunar orbital devation from the ecliptic happening at the same locations as the solstices. These rising positions seemed to be important to the ancients for practical and nonpractical reasons.**
    a. **<u>Stonehenge</u>: For practical reasons the major and minor standstill positions could be used to predict the occurrence of lunar eclipses.**
    b. **<u>Ancestral Puebloans</u>: The Chimney Rock site highlighted the major standstill position of the moon between two distinctive pinnacles. The 19 spirals of the Fajada Butte Sun Dagger may have represented the changing rising position of the moon over the duration of an 18.6 year period and thus highlighted these maximum extremes. Keep in mind that early humans thought in whole numbers only.**

9. **<u>MINOR STANDSTILL POSITIONS</u>: It is the extreme locations in declination below the summer solstice position and above the winter solstice location. The moon is on the celestial equator side of the solstice positions. The declination of the moon would be +/- 18.5 degrees (-23.5º + 5º or +23.5º - 5º). Observations of**

these positions could have also been used in the prediction of lunar eclipses.

10. **STONEHENGE LAB: Students will complete the lab on Stonehenge found in the textbook.**
    a. **Note the location of summer solstice sunrise.**
    b. **Note the location of winter solstice sunrise.**
    c. **Sketch the line of site for the winter solstice sunset.**
    d. **Draw the alignment for the summer solstice sunset.**
    e. **Determine the relationship between the "Y" and "Z" holes and the lunar phase period**
    f. **Stonehenge maps often show declination positions along the horizon which correspond to major and minor standstill locations. Illustrate.**

11. **SOLAR AND LUNAR ECLIPSES:**
    a. **Eclipses are phase-related. Solar eclipses can only happen when the moon is new, and lunar eclipses can only occur when the moon is full.**
    a. **Sidereal (27.4 d) and Synodic periods (29.5 d): Eclipses are a function of the synodic period of the moon.**
        1) **Sidereal: 27.3 days—Orbital period of moon around the Earth.**
        2) **Synodic: 29.5 days—Phase period of the moon—from one phase to the next similar phase. This serves as the main "beat" for the repetition of all eclipses.**
    b. **Lunar orbit inclined to ecliptic by 5º:**
        1) **Demonstrate why this 5º inclination causes the sun to pass below or above the sun on most months. It also creates the minimum number of eclipses which can occur during a year's time, two lunar and two solar eclipses.**
        2) **A solar or lunar eclipse can only occur when the moon is at or near a node. A node is the intersection points between two planes.**

c. Two basic conditions that produce a solar eclipse and a lunar eclipse: Using daily/annual motion and the moon locked on a full phase, students can predict the month that the next solar or lunar eclipse will occur.
  1) Moon must be new (solar) or a full (lunar) phase.
  2) Moon must be at or near a node. The node or crossing point can be shown by watching the motion of the sun or the Earth's shadow move along the ecliptic.

d. Regression of the moon's nodes
  1) Allows for eclipses to happen in all parts of the sky. The ascending and descending nodes move westward (regress) so that in a period of 18.61 years, they circle the entire sky. Each year, the eclipse seasons move backwards by nearly 20 days (19.62 d).
  2) Eclipse season/eclipse year: The interval of time necessary for the sun to pass the same node twice. Because the nodes are regressing westward, this period is less than a full year. It is equivalent to 346.6 days.

e. Lunar Eclipse: Use the lunar eclipse projector to demonstrate the visual appearance of a lunar eclipse.

f. Archaeoastronomy: Show how major and minor standstill positions of the moon can allow for the prediction of seasonal eclipses. This may have occurred at Stonehenge in England.

12. PLANETARY MOTIONS AND NOMENCLATURE:

a. Inferior planets: Mercury and Venus

b. Superior planets: Jupiter, Saturn, Uranus, and Neptune

c. Earth: It is the position of observation, so Earth is neither an inferior or a superior planet.

d. Inferior planetary configurations and motions: With the sun on the meridian, show the motion of the inner planets, Mercury and Venus, as they orbit the sun. Identify the four major elongations or configurations.
  1) Greatest eastern/western elongation:

a) <u>Greatest Eastern Elongation</u>: Inferior planet is in the west after sundown at its greatest angle east of the sun.

b) <u>Greatest Western Elongation</u>: Inferior planet is in the east before sunrise at its greatest angle west of the sun.

2) <u>Conjunctions</u>: A coming together or a meeting.

a) <u>Inferior Conjunction</u>: Inferior planet has an elongation of zero and lies between the Earth and the sun.

b) <u>Superior Conjunction</u>: Inferior planet has an elongation of zero with the planet positioned on the opposite side of the sun. The sun is in the middle.

e. <u>Superior planetary configurations and motions</u>: Show major configurations of outer planets and demonstrate retrograde motion of a superior planet. Explain the optical illusion of why a planet appears to move westward in the sky. Show the same for an inferior planet.

1) <u>Conjunction</u>: Superior planet has an elongation of zero degrees and is positioned on the other side of the sun. The rising and setting times are similar to the sun's rising and setting times.

2) <u>Opposition</u>: Superior planet has an elongation of 180^o, opposite to the sun and the Earth. It is visible for the entire night. Its rising and setting times are opposite to the sun's rising and setting times.

3) <u>Eastern and Western Quadratures</u>: Superior planet has an elongation of 90^o from the sun.

a) <u>Eastern Quadrature</u>: Superior planet is visible in the evening sky after sundown.

b) <u>Western Quadrature</u>: Superior planet is visible in the morning sky before sunrise.

4) <u>Retrograde motion</u>: Movement of the planet against the background of stars is towards the west. It is caused by the perspective of a faster moving object

passing a slower moving body. Earth is the faster moving planet. The analogy is the same as a faster moving car passes a slower moving vehicle. The slower moving car appears to be move backwards from the perspective of the faster moving vehicle.

a) **<u>Inferior Planet</u>: moves between Earth and sun during inferior conjunction.**
b) **<u>Superior Planet</u>: Earth passes slower moving planet which appears to move westward (backwards) among the stars.**

13. **<u>CONSTELLATIONS</u>: Constellations will be introduced within all the laboratory exercises in the planetarium.**
    a. **<u>Define constellations</u>: A named region of the heavens which has borders (boundaries) and is officially acknowledged by the International Astronomical Union (1928). Stars within that boundary may or may not represent a picture similar to the constellation's name. The picture is not important; the boundaries are important.**
    b. **<u>North Circumpolar Group</u>: Big Dipper (Ursa Major), Little Dipper (Ursa Minor), North Star, motion of stars around Polaris, Draco, Cassiopeia, Cepheus…**
        1) **<u>Pointer Stars</u>: Dubhe and Merak can be easily used to find the North Star.**
        2) **<u>Motion of stars around the North Celestial Pole</u> which is very close to Polaris.**
        3) **<u>Asterisms</u>: A group of stars which form a picture not officially accepted by the International Astronomical Union. The Big Dipper is not a constellation. It is culturally significant only to Americans.**
        4) **<u>Drinking Gourd</u>: Origin of America's Big Dipper came from a southern carpenter named Peg Leg Joe, who taught the "Drinking Gourd" song to slaves in the antebellum South.**

c. <u>Winter Group</u>: Orion, Taurus (Pleiades), Canis Major and Minor, Gemini, Auriga.

1) **<u>Orion's stars named</u>: Orion is one of the principal constellations which can be used to find other star patterns.**
2) **<u>Location of Sirius</u>, the brightest star of the night and its comparison to the North Star.**
3) **<u>Asterisms of Winter</u>: Orion's belt, called the "Three Mary's" in South American, the <u>Pleiades</u> and <u>Hyades</u>, both star clusters in Taurus the Bull, represent some of the most famous and obvious asterisms in the sky.**
4) **<u>Heavenly "G"</u>: Formed by the bright winter stars surrounding and including Orion the Hunter.**
5) **<u>Colors of stars</u> are an indication of temperature with blue stars the hottest and red stars the coolest.**
6) **<u>Stellar Birth and age differences</u>: Orion Nebula, Pleiades, Hyades represent a sequence of star clusters from forming (Orion Nebula) to mature (Hyades)**
7) **<u>Supernova of 1054</u> (Crab Nebula-M1)—explain M objects.**

d. <u>Spring Group</u>: Leo, Bootes, Virgo, Draco/Hercules, Corvus, Hydra.

1) **<u>Emphasize that we are looking away from the</u> center of the Milky Way galaxy. Because there is less obscuring dust we can see many clusters of galaxies in the directions away from the Milky Way. The same situation occurs in the late autumn sky.**
2) **<u>Use of Pointer Stars</u> of the Big Dipper to find Leo the Lion, and the handle of the Dipper to locate the bright stars, Arcturus and Spica.**

e. <u>Summer Group</u>: Cygnus, Aquila, Lyra (Great Summer Triangle—asterism) Ophiuchus, Serpens, Sagittarius, and Scorpius.

f. <u>Fall Group</u>:

1) **Perseus, Pegasus, Andromeda, Aries, Pisces, Aquarius, Capricornus.**
2) **Emphasize the location of the Andromeda Galaxy and the double cluster of Perseus.**
3) **Asterisms: The Great Summer Triangle, The Great Square of Pegasus.**
4) **Lonely Fomalhaut: It is a symbol of the autumn sky which can be located by taking the two western stars of the Great Square of Pegasus and allowing them to point southward.**

Gary A. Becker
September 12, 2017
2018

NOTES