SESSION TWO: POPULAR MISCONCEPTIONS IN ASTRONOMY

Name _____ Date _____ Moravian University

PROJECT STAR ACTIVITY-Harvard University/revised Moravian University Astronomy
A Basic Test of Astronomical Facts and Concepts

1. One night we looked at the moon and saw:

A few days later, we looked again and saw this:

What do you think best describes the reason for this change?

a. Clouds block the moon.
b. The moon moves into the sun's shadow.
c. The moon moves around the Earth.
d. The moon passes the planets and goes in and out of their shadows.
e. The moon moves into the Earth's shadow.
f. The moon is black and white and rotates.
g. The Earth moves around the moon.

2. What causes night and day?

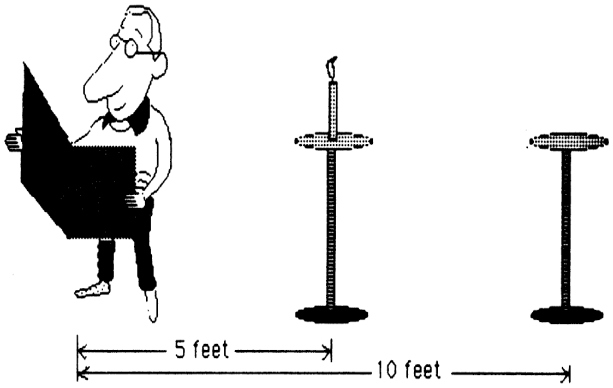
a. The Earth spins on its axis.
b. The moon blocks out the sun's light.
c. The sun goes around the Earth.
d. The Earth moves around the sun.
e. The Earth moves into the sun's shadow.

3. True Story: On October 17, 1604, Johannes Kepler went outside, looked up, and saw a bright new star in the foot of the constellation of Ophiuchus the Serpent Holder, what astronomers call a supernova. When do you think the star exploded?

a. Before October 17, 1604.
b. On October 17, 1604.
c. After October 17, 1604.

4. The man is reading a newspaper by the light of a single candle five feet away. Indicate the number of candles necessary to light up the paper to the same brightness, if the candleholder was moved to a distance of 10 feet from the newspaper.

a. 1 candle
b. 2 candles
c. 3 candles
d. 4 candles
e. 5 candles
f. more than 5 candles



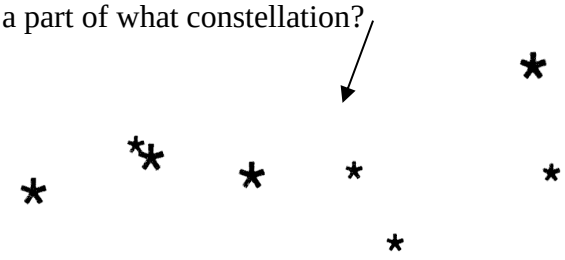
5. What causes the seasons?

a. The Earth's distance from the sun...
b The Earth's axis flipping back and forth as it travels around the sun…
c. The sun's motion around the Earth…
d. A tilted axis pointing in the same direction…
e. The shifting seasons on the Earth…
f. The change in the amount of daylight…

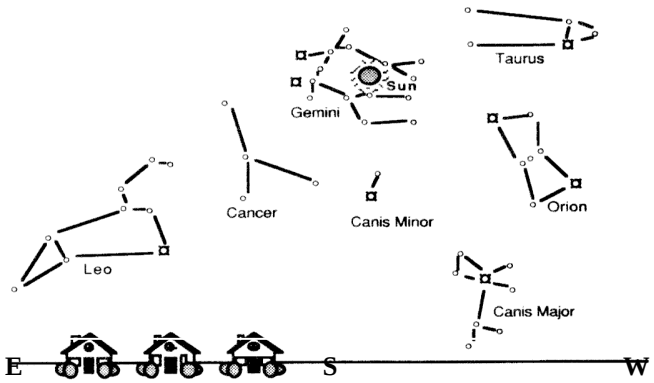
6. Which answer goes from smallest size to largest size?
   a. sun < Earth < moon
   b. Earth < moon <sun
   c. moon <sun < Earth
   d. sun < moon < Earth
   e. Earth < sun < moon
   f. moon < Earth <sun

7. What time could it be if you saw a thin crescent moon near the western horizon?
   a. sunrise
   b. noon
   c. anytime of the day or night
   d. sunset
   e. midnight
   f. not possible

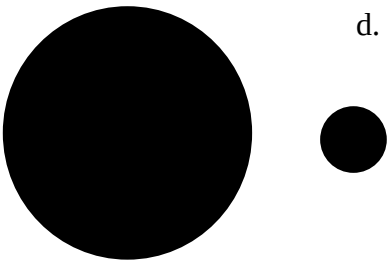
8. These stars are a part of what constellation?
   a. Orion
   b. Ursa Major
   c. North Star
   d. Pleiades
   e. Big Dipper



9. If you could see stars during the day, this is what the sky would look like at noon on a given day. The sun is in the constellation of Gemini. In what constellation would the sun be located at sunset?
   a. Leo
   b. Canis Major
   c. Gemini
   d. Cancer
   e. Taurus



10. Assume these circles represent two objects in the solar system with their diameters drawn to scale. Which objects could they represent?
    a. Earth and moon
    b. sun and Earth
    c. Jupiter and Earth
    d. sun and Jupiter

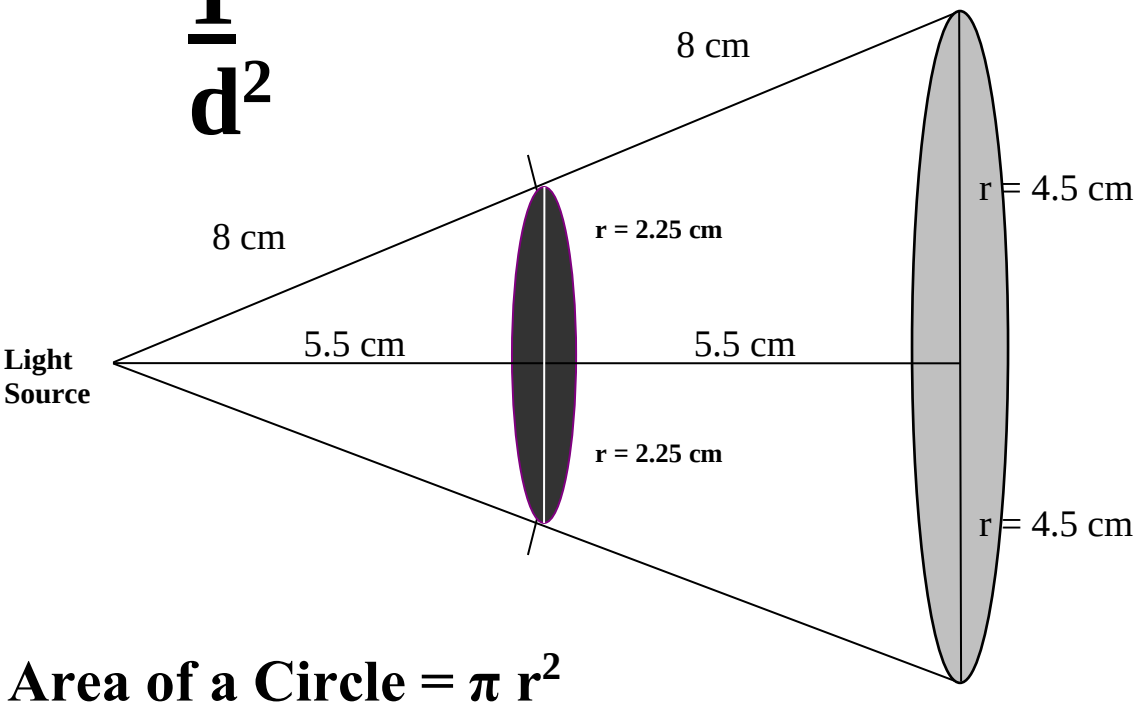


11. What is the brightest star of the nighttime sky?
    a. Venus
    b. Sirius
    c. North Star
    d. sun

Inverse Square Law

Electromagnetic Energy/Magnetism/Gravity

$$\frac{1}{d^2}$$

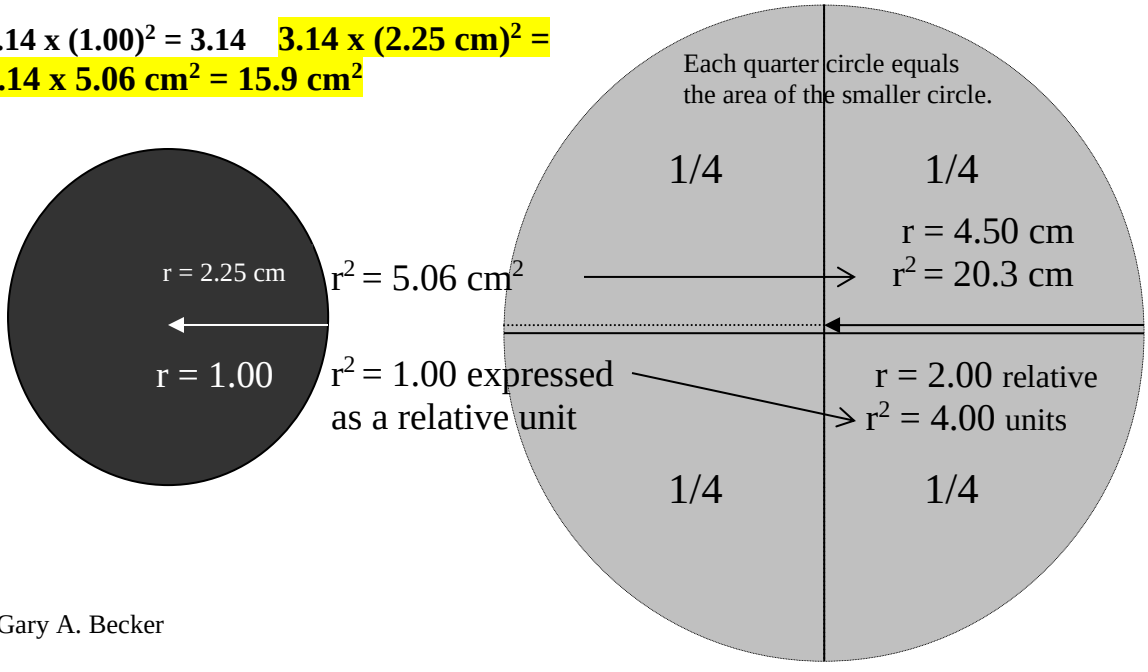


Area of a Circle = πr^2

$\pi = 3.14$

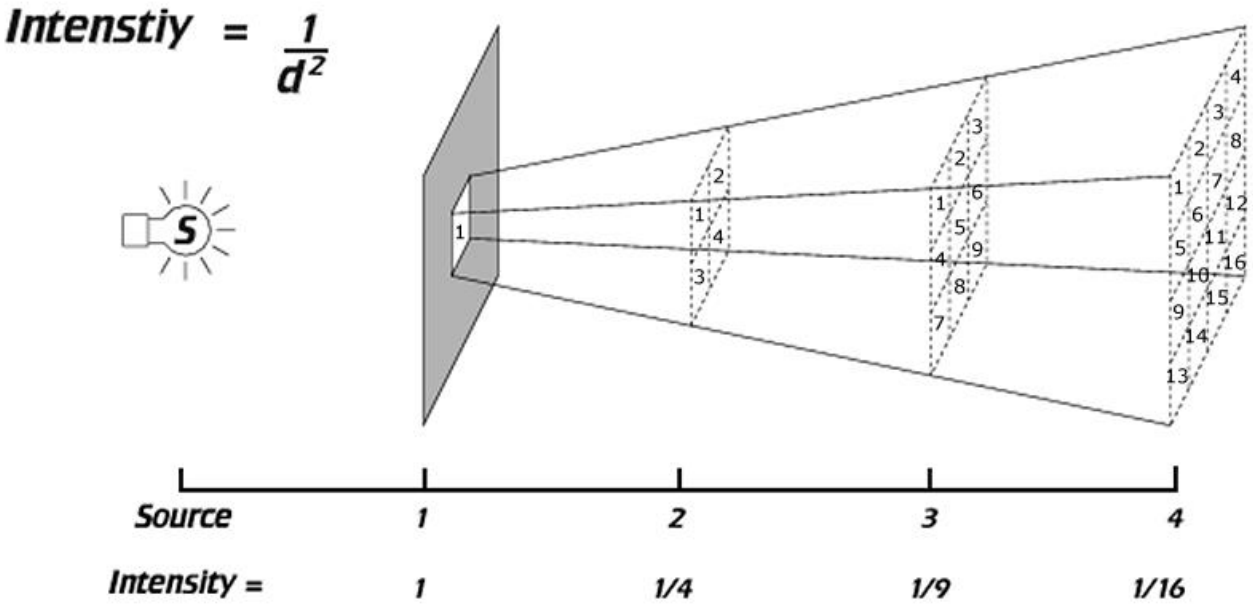
$3.14 \times (2.00)^2 = 3.14 \times 4.00 = 12.6$
Size of cone when the distance is doubled
$3.14 \times (4.50\ cm)^2 = 3.14 \times 20.3\ cm^2 = 63.7\ cm^2$

$3.14 \times (1.00)^2 = 3.14$ **$3.14 \times (2.25\ cm)^2 = 3.14 \times 5.06\ cm^2 = 15.9\ cm^2$**



Gary A. Becker

Inverse Square Law



NOTES

BASIC MISCONCEPTIONS WORD LIST

1. **Acceleration:** A change in velocity over a change in time.
2. **Albedo:** The reflectivity of an astronomical object expressed as a percentage of the total light available.
3. **Alpha Centauri:** The triple star system which is nearest to the sun and which contains Proxima, the faintest star of the group and the closest star to our sun. Proxima is 4.22 light years in distance.
4. **Angular Diameter:** The size of an object measured against a spherical coordinate system.
5. **Anomalistic Month:** The time period between two successive perigee or apogee positions of the moon.
6. **Aphelion:** The Earth's greatest distance from the sun, 94,509,100 miles/ 152,097,700 kilometers.
7. **Apogee:** The moon's farthest distance from the Earth, 251,900 miles/405,400 kilometers.
8. **Asterism:** A pattern of stars often popular with a culture for conveying a picture, but not officially adopted as a constellation by the International Astronomical Union in 1928.
9. **Astrology:** A pseudoscience which claims to predict human behavior or national events through the interpretation of the positions of the sun, moon, planets, and stars.
10. **Aurora:** The ionization effects produced by electric currents which descend through the Earth's upper atmosphere. The electrons are trapped in Earth's magnetosphere (magnetic envelope). The origin of this plasma comes from solar coronal mass (plasma) ejections.
11. **Big Dipper:** The most famous American asterism. Its origin probably has its roots in the Drinking Gourd of the antebellum (pre-Civil War) South.
12. **Blue Moon:** The second full moon occurring during the time period of one month.
13. **Burning:** The thermonuclear fusion of lighter elements into heavier elements within the cores or shells of stars. It has nothing in common with combustion.
14. **Celestial Poles:** The point of intersection in the northern and southern sky of the Earth's axis with the celestial sphere (North Celestial Pole, South Celestial Pole).
15. **Celestial Sphere:** The dome of the heavens surrounding Earth and which is concentric to Earth's center.
16. **Constant:** A value in a mathematical equation which remains fixed and which gives quantitative units within a specific measuring system (MKS, CGS, English, etc.).
17. **Constellation:** A named area of the celestial sphere surrounded by official boundaries that were created and sanctioned by the International Astronomical Union in 1928. Stars within the boundary can be connected to form a picture; however, the stars which are employed have no official IAU approval.
18. **Copernicus, Nicolas:** (1473-1543) The Polish philosopher who reawakened Europe to the Greek notion that our universe was heliocentric (sun-centered).
19. **Crescent:** horned, referring to a phase of the moon… a crescent moon.
20. **Dark Side:** The perpetually unlit hemisphere of the moon. It is a misconception. The entire moon goes through a day and night cycle over the course of its 29.5 day phase period which is easily witnessed from Earth.
21. **Far Side:** The portion of the moon (41 percent of its surface) which cannot be seen from the Earth's surface.
22. **First Quarter:** The lunar phase which occurs when the sun-Earth-moon angle is equal to 90 degrees. The moon appears half on, half off, with its light to the right.

23. **Full Moon:** The lunar phase which happens when the moon reaches opposition to the sun as witnessed from Earth. The sun-Earth-moon angle is equal to 180 degrees.
24. **Galileo Galilei:** (1564-1642) The Italian astronomer and physicist who first turned his telescopes to the heavens and then published his observations (***Sidereus Nuncius-Starry Messenger***-1610). Galileo did not invent the telescope, nor was he the first to use the telescope to view the sky.
25. **Gagarin, Yuri A.:** (1934-1968) The first human to orbit the Earth successfully and return safely. He was Russian, and his flight occurred on April 12, 1961.
26. **Gas Giants:** The four outermost planets, Jupiter, Saturn, Uranus, and Neptune. They have extensive gaseous atmospheres, but are mostly liquid in their interiors. The concept that they are composed of elements in a gaseous phase is a misconception.
27. **Geocentric:** Earth-centered…
28. **Gibbous:** Convex on both sides… For the moon's phases, the limb (edge) of the moon is convex as well as the terminator (day and night boundary).
29. **Glenn, John H., Jr.:** (1921-2016) The third American to rocket into space and the first American to orbit the Earth. Glenn returned to space as a Payload Specialist at a record age of 77 on the Space Shuttle ***Discovery*** (STS-95) on October 29, 1998.
30. **Heliocentric:** Sun-centered…
31. **International Date Line:** A boundary approximately at the 180 degree meridian which rectifies the loss or gaining of time by westward or eastward travelers respectively.
32. **Last Quarter:** The final or second time in a lunar phase period, where the sun-Earth-moon angle is equal to 90 degrees.
33. **Leap Year:** The method by which the Earth's orbital period of 365.24 days is rectified with the calendar year of 365 days. Calendar years divided by four become leap years except for century years which must be divisible by 400.
34. **Librations:** A wobbling effect which the moon goes through each rotation as a result of Earth's position and the moon's position in space. Over a 30-year period, astronomers get to view 59 percent of the lunar surface.
35. **Limb:** The boundary of an astronomical object as it appears against the sky.
36. **Lippershey, Hans:** (1570-1619) The Dutch optician who first applied for a patent for the telescope. His application was rejected because of the telescope's simplistic design. Lippershey is most often considered the inventor of the telescope.
37. **Magnification:** The visible enlargement of an object by an optical instrument. In a telescope it is the focal length of the light-gathering objective divided by the focal length of the eyepiece.
38. **Meridian:** The great circle on the celestial sphere which intersects the horizon at the north point, the south point, and the zenith. It must also pass through the north and south celestial poles.
39. **Meteor:** The flash of light created by the incandescence (ionization) of the Earth's atmosphere as a small piece of natural space debris passes through it. Meteors are related to comets.
40. **Meteorite:** A piece of natural space debris which passes through the atmosphere and impacts onto the Earth's surface. Meteorites are always related to asteroids.
41. **Meteoroid:** The term given to small space debris from comets or asteroids in orbit around the sun. It also applies to this material as it is plummeting toward the Earth's surface.
42. **Moon Illusion:** The psychological phenomenon where the brain interprets the moon to be larger than it actually is when it is near to the horizon.

43. **New Moon:** The phase of the moon as seen from Earth when the sun-Earth-moon angle equals zero. The moon is viewed in the same direction as the sun, making it invisible because the hemisphere facing Earth is in its own shadow. The phase of the moon during a solar eclipse.
44. **Newton, Isaac:** (1642-1727) The English physicist, who first quantified gravity, investigated the properties of light, independently co-invented the calculus, and built the first reflecting telescope (1668). Newton also wrote the single most important book in science, the ***Principia Mathematica*** published in 1687.
45. **North Star:** The nearest bright star to the North Celestial Pole. The sky in the northern hemisphere seems to pivot about this point.
46. **North Pole:** The point on the Earth's surface located at 90 degrees north latitude, where all directions face south. The location north of the equator where all circles of longitude intersect.
47. **North Magnetic Pole:** The direction to which compass needles point. The location on Earth's surface from which Earth's magnetic field emerges. It is not the same as the North Pole.
48. **Nucleosynthesis:** The processes by which lighter elements are fused into heavier elements inside of stars.
49. **Perigee:** The moon's closest distance to the Earth, 225,700 miles/384,400 kilometers.
50. **Perihelion:** The Earth's closest position to the sun, 91,402,500 miles/ 147,098,070 kilometers from the Sun's center.
51. **Polaris:** Another name for the North Star or Pole Star.
52. **Pole Star:** Another name for the North Star or Polaris.
53. **Quarter Moon:** Any of two lunar phases that occur at an elongation of 90 degrees from the sun in which the terminator appears as a straight line.
54. **Reflector:** A telescope which gathers and brings light to a focus by bouncing it off a concave mirror.
55. **Refractor:** A telescope which gathers and brings light to a focus by passing it through a lens or series of lenses.
56. **Shepard, Alan:** (1923-1998) The first American astronaut (second human) launched into space (1961). Shepard's mission was suborbital. Alan Shepard later walked on the moon.
57. **Sidereal Period:** Referenced to the moon, the time required for one orbit of the moon around the Earth.
58. **Space (relativity):** length, width, and height
59. **Synodic Period:** With reference to the moon, the time required for the moon to complete one phase cycle.
60. **Sunspot:** A magnetically active, region of the sun's photosphere (light emitting layer) in which normal convection (heat transport) has been slowed. The magnetically active area is cooler and therefore less bright, appearing dark against the sun.
61. **Telescope:** An astronomical device primarily used for gathering light from distant objects. The images are magnified to make them more clearly seen.
62. **Terminator:** The dividing line on the lunar surface between day and night. When the moon is waxing, night is changing into day. Then the moon is waning, day is changing into night.
63. **Time:** The interval between two distinct events. A moment, hour, day, or year as indicated by a clock or calendar (Webster's Online Dictionary).
64. **Waning:** To grow smaller…
65. **Waxing:** To grow larger…

NOTES

ASTRONOMY AND ASTROLOGY

***MISCONCEPTION*—**ASTRONOMY AND ASTROLOGY ARE INTERCHANGEABLE:
TRUTH: **ASTRONOMY** is the science which investigates all matter-energy in the universe. It is based upon the scientific method, which states that theories must be grounded upon observational facts and endure repeated testing as new observational information is acquired.
ASTROLOGY is the pseudoscience which entertains how the relationships of the sun, moon, planets, and stars influence the attitudes and lives of humans. The predictions purported by astrologers have been shown to have no scientific basis in themselves and were the synthesis of Claudius Ptolemy, a Greek astronomer. About 140 AD Ptolemy wrote a series of four books called the ***Tetrabiblos*** which summarized all of the principles of astrology which are still practiced today. Astrology began about 3,000 years ago in Babylon with what we today call **mundane** astrology. Predictions were applied to world or national events. To meet these needs, Babylonian astronomers were required to keep a continuous record of accurate planetary movements which in themselves were good astronomy. They did not seek answers to questions about the physical universe but attempted to understand the motions of celestial objects in more of a mechanistic fashion. By the sixth century BC astrology had spread as far east as India where it still flourishes today. Meanwhile, the Egyptians modified Babylonian concepts by developing a more personal version of astrology which was later synthesized into **natal** astrology by the Greeks after the conquests of Alexander the Great. The Greeks believed that our lives were preordained by the precise configuration of the sun, moon, and planets in the sky at the moment of our birth. This astrology is still practiced today by Europeans and Americans along with **horary** astrology which provides the daily horoscopes found in newspapers and tabloids alike.

DEMONSTRATION: The class is divided into two groups. Everyone must be aware of his/her astrological sign (Taurus, Gemini, Virgo, etc.). The first group receives a sheet of paper detailing the astrological traits for each sign. The second group receives the same information without the correlation of their sign to its traits. Each group is asked to choose the set of characteristics which best corresponds to his or her traits as envisioned by the student. Pupils who observe their astrological sign along with its traits will be more likely to correlate their traits with their sign. Students who only read about astrological traits will be more likely to select randomly with no correlation of the traits to their sign.

SUN SIGN TRAITS

Instructions: Find the sun sign qualities which best describe your personal traits. Circle the number. Complete the questions below.

_____ Which number best describes the personal traits which you believe to possess?
_____ Sun sign of student
_____ Yes/No: Did you agree with your sun sign personality traits?

Number	Key Words	Personality Description
1.	possessions, determined, practical	achieves mastery over physical matter, fond of the good things of life; love of comfort, satisfaction, and pleasure; fond of good clothing and impressed by the appearance of others, extremely jealous, strong willpower…
2.	regeneration, resourceful, secrecy	power, will, intense emotional desires, wants to do everything perfectly, ardent defenders of justice; excels in work involving detection, science, research, and the occult; highly secretive, not inclined to fear, generally of robust and strong health…
3.	initiative, activity, enterprise	aggressive and direct in expressions, tremendous drive to prove himself to others, impatient, does not always finish what he starts, highly competitive, good leadership qualities, refuse to admit to defeat…
4.	vitality, authority, power	enjoys being the center of attention, wants to have children, gives of himself generously, strong attraction to the opposite sex, dislikes repetition, is overly frank and confident, stately, noble, likes to set policy, reckless courage…
5.	compassion, universality, self-denial	responsive to the thoughts of others, easily influenced, unable to make decisions, not combative, not ambitious for material or monetary acquisitions, creative, enjoys being enveloped in a dream world where he can forget about himself, overactive imaginations, wants to initiate healing and relief…
6.	domestic, sensitive, steadfast	good homemaker, sensitive, fearful of ridicule, finds security in solitude, seldom gambles, pays debts, noted for diplomacy, hurt easily, great love of children, avoids mental or physical discomfort, clean, does not like to be told what to do…
7.	intelligence, versatile, nonconformist	thinks and acts swiftly, identifies, classifies, communication is especially important, thirsty and eager to study, variety is the spice of life, high-strung but rarely loses control, curious, fond of travel, money is power…
8.	harmony, companionship, balance	charm and grace in expression, desires popularity, will initiate activities, seeks cooperation of others, marriage and partnerships are primary concerns, strong sense of justice, actively seeks knowledge and mental stimulation, rarely expresses anger...
9.	ambitious, conservative, organized	ambitious, excellent intuition, steady, sure-footed, loves law and order, believes that hard work is linked to material security, great faith in their own powers, successful troubleshooters, makes excellent executive, tight with money…
10.	aspiration, love of freedom, exploration	deeply loves liberty and freedom, energetic and naturally outgoing, serious thinkers, concerned with well-being of society; honest, just, and generous; often jumps to conclusion before taking all factors into consideration, likes excitement through adventure, travels far and fast, women are highly independent...
11.	humanitarian, independent, original	friendship and companionship are important, eccentric temperaments, determined, stubborn, never lonely, instinctively drawn towards people; likes material possessions, but is not greedy; likes to watch sports, works best in groups, sympathy for human problems…
12.	discriminating, orderly, service	seeks knowledge, focuses on work, likes to bring order from confusion, best suited for service careers, healthy, likes good food, fond of comfort and good clothes, likes to spend money, stays single…

SUN SIGN TRAITS

Instructions: Find the sun sign qualities which best describe your personal traits. Circle the number. Complete the first questions below.

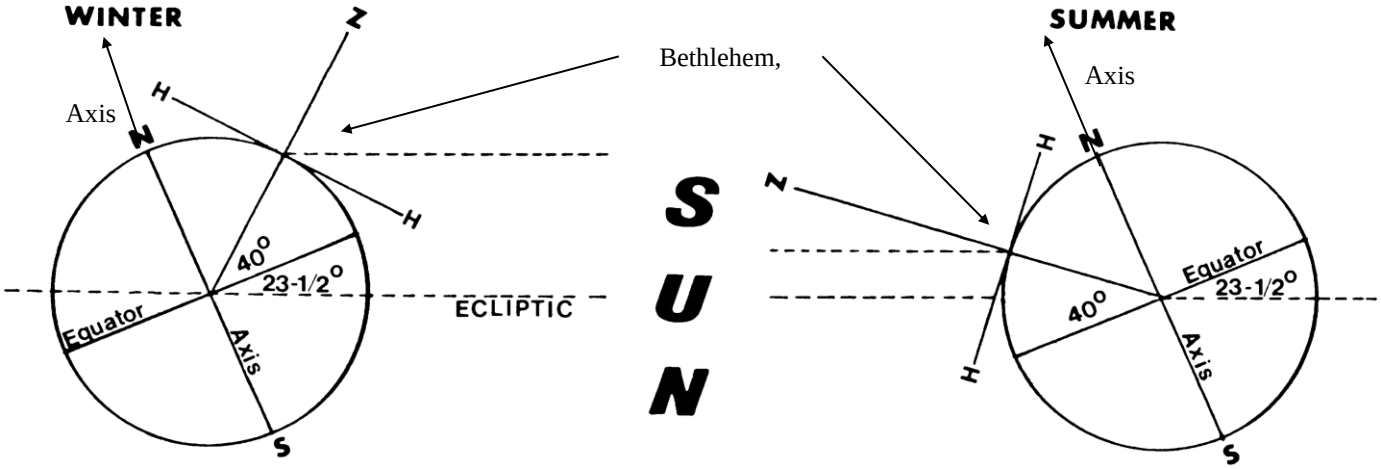
_____ Write the number which best describes the personal traits that you believe to possess?
_____ What is the date of your birthday?
_____ Yes/No: Did you agree with your sun sign personality traits?

Number	Key Words	Personality Description
1. ARIES 03-21/04-19	initiative, activity, enterprise	aggressive and direct in expressions, tremendous drive to prove himself to others, impatient, does not always finish what he starts, highly competitive, good leadership qualities, refuse to admit to defeat…
2. TAURUS 04-20/05-20	possessions, determined, practical	achieves mastery over physical matter, fond of the good things of life; love of comfort, satisfaction, and pleasure; fond of good clothing and impressed by the appearance of others, extremely jealous, strong willpower…
3. GEMINI 05-21/06-21	intelligence, versatile, nonconformist	thinks and acts swiftly, identifies, classifies, communication is especially important, thirsty and eager to study, variety is the spice of life, high-strung but rarely loses control, curious, fond of travel, money is power…
4. CANCER 06-22/07-22	domestic, sensitive, steadfast	good homemaker, sensitive, fearful of ridicule, finds security in solitude, seldom gambles, pays debts, noted for diplomacy, hurt easily, great love of children, avoids mental or physical discomfort, clean, does not like to be told what to do…
5. LEO 07-23/08-22	vitality, authority, power	enjoys being the center of attention, wants to have children, gives of himself generously, strong attraction to the opposite sex, dislikes repetition, is overly frank and confident, stately, noble, likes to set policy, reckless courage…
6. VIRGO 08-23/09-22	discriminating, orderly, service	seeks knowledge, focuses on work, likes to bring order from confusion, best suited for service careers, healthy, likes good food, fond of comfort and good clothes, likes to spend money, stays single…
7. LIBRA 09-23/10-22	harmony, companionship, balance	charm and grace in expression, desires popularity, will initiate activities, seeks cooperation of others, marriage and partnerships are primary concerns, strong sense of justice, actively seeks knowledge and mental stimulation, rarely expresses anger...
8. SCORPIO 10-23/11-21	regeneration, resourceful, secrecy	power, will, intense emotional desires, wants to do everything perfectly, ardent defenders of justice; excels in work involving detection, science, research, and the occult; highly secretive, not inclined to fear, generally of robust and strong health…
9. SAGITTARIUS 11-22/12-21	aspiration, love of freedom, exploration	deeply loves liberty and freedom, energetic and naturally outgoing, serious thinkers, concerned with well-being of society; honest, just, and generous; often jumps to conclusion before taking all factors into consideration, likes excitement through adventure, travels far and fast, women are highly independent...
10. CAPRICORN 12-22/01-19	ambitious, conservative, organized	ambitious, excellent intuition, steady, sure-footed, loves law and order, believes that hard work is linked to material security, great faith in their own powers, successful troubleshooters, makes excellent executive, tight with money…
11. AQUARIUS 01-20/02-18	humanitarian, independent, original	friendship and companionship are important, eccentric temperaments, determined, stubborn, never lonely, instinctively drawn towards people; likes material possessions, but is not greedy; likes to watch sports, works best in groups, sympathy for human problems…
12. PISCES 02-19/03/20	compassion, universality, self-denial	responsive to the thoughts of others, easily influenced, unable to make decisions, not combative, not ambitious for material or monetary acquisitions, creative, enjoys being enveloped in a dream world where he can forget about himself, overactive imaginations, wants to initiate healing and relief…

THE EARTH

MISCONCEPTION—THE SEASONAL EFFECTS ARE THE RESULT OF THE EARTH'S AXIS FLIPPING BACK AND FORTH:

TRUTH: The Earth's axis does slowly wobble like a top, completing one cycle in approximately 26,000 years. This motion is called precession, and it is responsible for a gradual change in the location of the position in the sky where the Earth's axis points. During the present epoch the Earth's axis is aimed toward Polaris, the North Star, in the constellation of Ursa Minor. It is around this star that the sky appears to pivot once each day as the Earth rotates on its axis. Nearly five thousand years ago, when the Great Pyramid at Giza was constructed, the Earth's axis pointed towards Thuban in the constellation of Draco the Dragon. Ironically, if the Earth's axis did flip back and forth during the interval of six months, it could be demonstrated that every position on Earth would experience the same seasonal effects throughout the year.



In the drawing, the Earth's axis is tilted 23.5° from the perpendicular to the ecliptic. The ecliptic represents the orbital plane of the Earth. Rays of sunlight striking the ground are represented as line segments parallel to the ecliptic. The angular measure of Allentown, PA is approximately 40° north of the equator. The Z represents the position of the zenith as seen from Allentown. The two H's are the horizons as seen from Allentown. The horizon closer to the North Pole is the northern horizon. The horizon closer to the equator is the southern horizon. The drawing shows the altitude of the sun at noon at the time of the winter and summer solstices. The angle described from the southern horizon to a line segment parallel to the ecliptic and intersecting the position of Allentown, represents the extreme altitudes of the sun at noon on the dates of the solstices.

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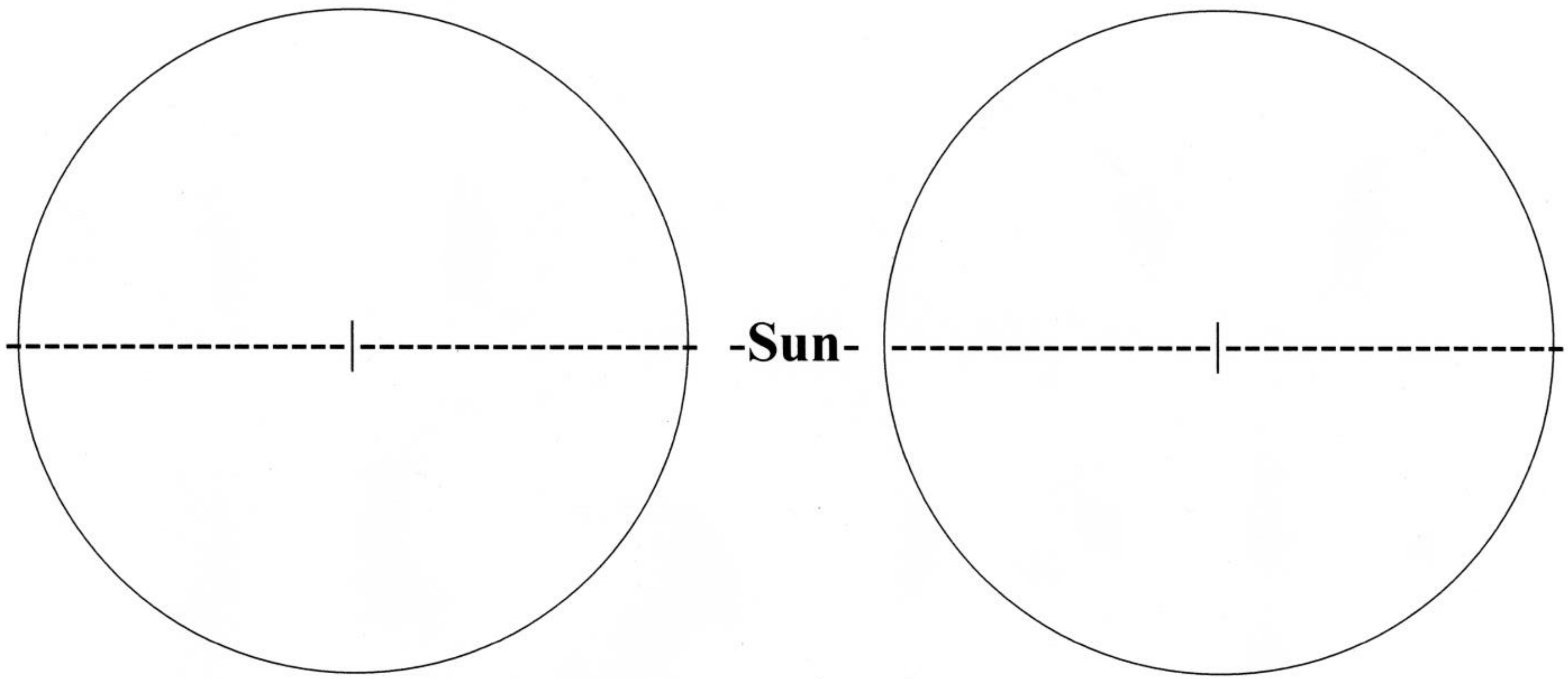
Geometry of the Seasons (12 points)



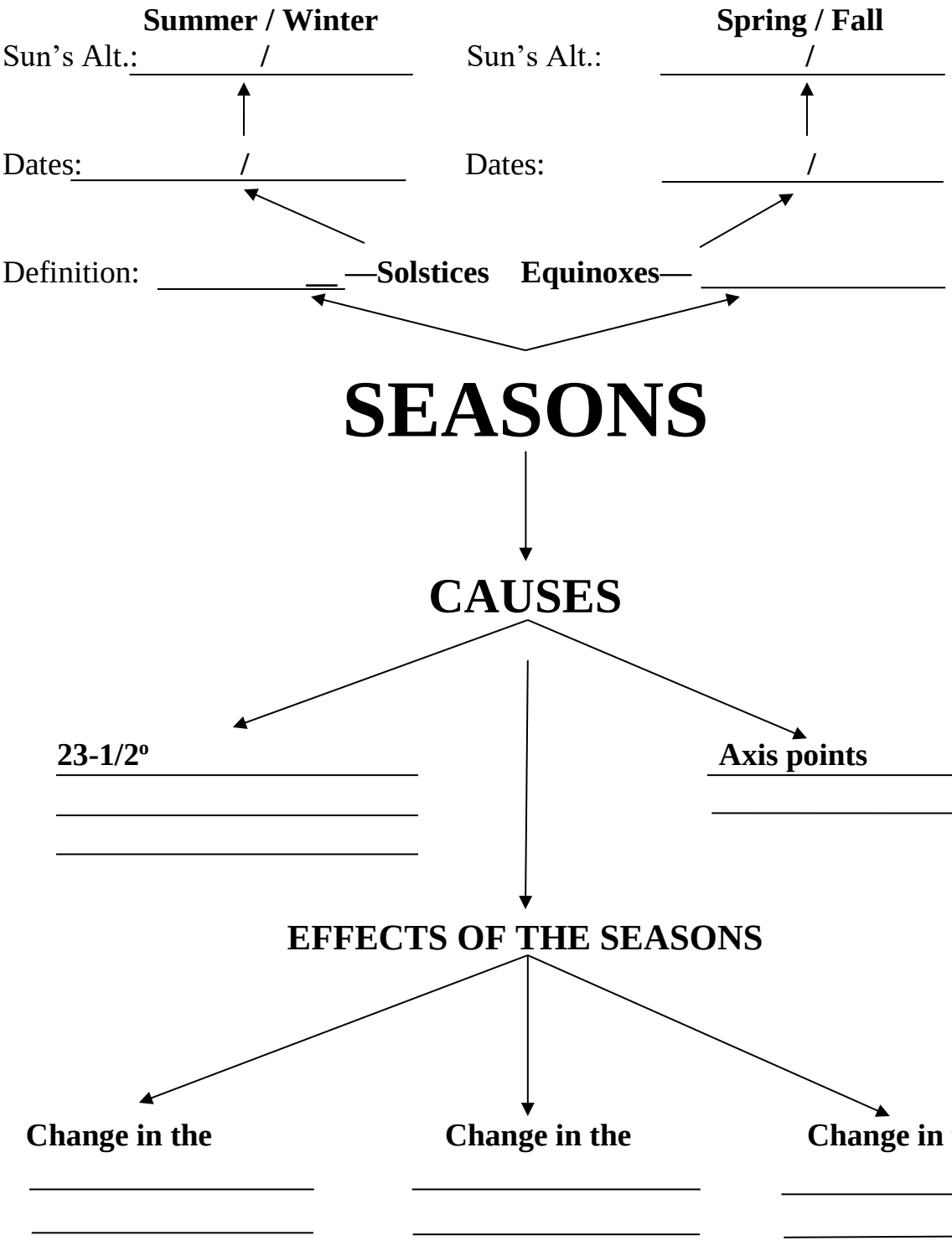
The Season is ____________________ **The Season is ____________________**

Complete this exercises IN PENCIL by drawing, labeling, to both sides and/or answering the following statements/questions accurately.

1. Sketch/label the ecliptic and perpendicular to the ecliptic for each Earth.	**(2)**	**6. Sketch/label Bethlehem's zenith position for both Earths.**	**(1)**
2. Draw/label for each Earth, the axis, tilted 23.5° from the perpendicular to the ecliptic. Indicate the 23.5° angle at the appropriate locations.	**(1)**	**7. Draw and label Bethlehem's north and south horizon positions for both Earths.**	**(1)**
3. Label the direction to Polaris (the North Star) for each Earth.	**(1)**	**8. Draw/label incoming rays of the sun at noon for Bethlehem on both Earths. (1) LABEL WHICH EARTH REPRESENTS SUMMER/WINTER.**	**(1)**
4. For both Earths, draw/label the equator which is located 90° away from the Earth's axis.	**(1)**	**9. _________ Measure the SUMMER noontime sun angle for Bethlehem. Note this angle at the appropriate location above and on the drawing.**	**(1)**
5. Draw/label Bethlehem's 40° north latitude position to the equator for each Earth. Label Bethlehem's location on each Earth.	**(1)**	**10. _________ Measure the WINTER noontime sun angle for Bethlehem. Note this angle at the appropriate location above and on the drawing.**	**(1)**

Name _____ Date _____ Moravian University

GRAPHIC ORGANIZER FOR THE SEASONS



WHY DO ALL OF THE STARS PIVOT AROUND THE POLE STAR? Stand under a ceiling and lean your head back. Pick a mark which is directly overhead. Your body is now the Earth, and your line of sight represents the Earth's axis projected into space. Now slowly rotate, and notice how all of the other parts of the ceiling seem to circle around the point which is fixed. As the Earth rotates, its axis projects outward into space, very near to the star that we call Polaris. If the seasons were created by the Earth's axis flipping back and forth, we would have a continuous change of pole stars in the sky throughout the course of a year.

MISCONCEPTION—THE FOUR SEASONS ARE THE RESULT OF THE CHANGING DISTANCE OF THE EARTH FROM THE SUN:
TRUTH: Most people believe this statement to be true. The seasons are caused in reality by the 23.5^{o} tilt of the Earth's axis and the axis always pointing in the same direction. During the course of a year, this one phenomenon changes the duration of time in which the sun is visible in the sky, the rising and setting positions of the sun along the horizon, and the noontime altitude of the sun. The Earth's orbit is slightly elliptical (oval) in shape. During a year's time the Earth's distance from the sun varies from approximately 91.5 to 94.5 million miles. We are actually closest to the sun around January 2nd of each year and farthest from the sun around Independence Day, exactly the opposite of what one might expect.
CONSIDER THE FACT that the Southern Hemisphere experiences summer when the Earth is closer to the sun. Are the summers in the Southern Hemisphere warmer? The answer is no. The Southern Hemisphere has less land. The excess heat is absorbed by the water which has an extremely high heat capacity. This moderates the summertime temperatures in the Southern Hemisphere.

MISCONCEPTION—THE EARTH ROTATES (SPINS) IN A PERIOD OF ONE DAY:
TRUTH: The Earth rotates on average in a period of 23 hours, 56 minutes, 4 seconds. This is defined as the sidereal day, and it is about four minutes shorter than the solar day which is used to regulate our clocks. During this interval, the Earth's revolution carries us about one degree along in our orbit. This causes the sun to be shifted by one degree to the east. Since we regulate our daily activities by the sun, we want the sun to return to its same noontime position of due south after a uniform interval of time has elapsed. It takes an extra four minutes of Earth rotation added to the sidereal day to accomplish this, creating the solar day which contains 24 hours.
DEMONSTRATION: Each day, the stars shift about one degree to the east as we continue to revolve around the sun, but we maintain the consistency of returning the sun to its original position in the sky in a period of 24 hours. This daily shift in the positions of the stars over the course of a year causes the seasonal changes of the constellations that we observe.

MISCONCEPTION—THE EARTH REVOLVES (ORBITS) THE SUN IN A PERIOD OF ONE YEAR:
TRUTH: Earth's tropical year, the interval of time between two successive solar crossings of the spring equinox, happens every 365.2422 days. Anyone familiar with the calendar knows that we give the Earth only 365 days to complete this task. Every year, our planet lags approximately 1/4-day behind schedule in completing its orbital duties. Four years of under correcting add up to approximately one full day, so a leap-day is added to the calendar to bring the Earth's orbital position back into general agreement with the sun and the seasons. If the calendar did not contain leap years, then the dates of the year would cycle backwards through the seasons in approximately 1500 years. Christmas would still be celebrated on December 25, but gradually this date would

slide into the autumn part of Earth's orbit and then the summer, while the dates of the solstices and equinoxes would become later by about one day every four years.

MISCONCEPTION—A LEAP YEAR OCCURS EVERY FOUR YEARS:
TRUTH: This is almost true. The exception occurs with century years which are not divisible by 400. The year 2000 was a leap year, but the century years of 1700, 1800, and 1900 were not leap years because they did not produce a whole number when divided by 400. This is the main difference between the older Julian calendar (45 BC) and our modern Gregorian calendar (1582) that is used for civil purposes. The reason for the change arose because the Julian calendar overcorrected for the leap year by approximately 11 minutes, 14 seconds per year. From the adoption of the Julian calendar on January 1, 45 BC to the onset of the Gregorian system in 1582, the first day of spring had slipped backwards by 14 days, from March 25 to March 11, causing the observance of Easter to fall on earlier and earlier dates. If this were not corrected, eventually Easter and Christmas would be celebrated at the same time of the year. The Gregorian calendar was adopted by the Catholic nations of Europe in 1582 during the papacy of Gregory XIII. During that year 11 days were dropped from the calendar so that the vernal equinox would occur on March 21. The day following October 4, 1582 became October 15. The calendar was now corrected to about 1 day in 3300 years. To correct the calendar to an even a greater extent, the years 4,000 AD and 8,000 AD will not be leap years.

MISCONCEPTION—THE AURORA IS CAUSED BY REFLECTED SUNLIGHT FROM THE ICE CAPS OF THE POLAR REGIONS:
TRUTH: The aurora is really an electrical discharge which occurs high in the Earth's atmosphere. Trapped protons and electrons from the Van Allen radiation belts, situated thousands of miles above the Earth's surface, follow lines of magnetic force down into the Earth's atmosphere where they strike gas molecules causing them to glow. The Earth's magnetic field creates two oval-shaped areas where the charged particle intensity is highest, and the auroras are most frequently observed. Auroral activity takes place at altitudes between 60 miles to 350 miles above the surface of the Earth. In the locations of greatest frequency, auroras can occur on about 250 nights during a year.

MISCONCEPTION—A COMPASS NEEDLE ALWAYS POINTS TOWARDS THE NORTH:
TRUTH: Since the north magnetic pole is located approximately 700 miles south of the Earth's true geographic North Pole, a compass needle will tend to point in the general direction of north. At positions where the true geographic north lies directly south of the north magnetic pole, a compass needle will point directly north. In any other location there will always be some deflection of the needle either to the east or to the west of the true north position. This is called magnetic declination. In the Lehigh Valley a compass needle points approximately 11 degrees to the west of true north.

MISCONCEPTION—THE EARTH WAS CONSIDERED TO BE FLAT DURING THE TIME
TRUTH: WHEN COLUMBUS DISCOVERED THE NEW WORLD:
This misconception is generally true for the uneducated masses, but not so for anyone who had received a formal education and who could read. Columbus could read, and he was familiar with Greek texts which spoke of a spherical Earth as well as the circumference of the Earth. It was the Earth's circumference that was in disagreement among European scholars of Columbus's time. Columbus thought that the Earth was about 18,000 miles in circumference, and that the East Indies

were only about 3000 miles away. Despite this misconception, Columbus was a keen observer who had sailed widely and who had witnessed the changes in the sky which were consistent with a spherical Earth. Convincing a superstitious crew that the Earth was round and not inhabited by monsters was more difficult.

DEMONSTRATION: There are many observational proofs that will show that the Earth is spherical. A favorite of mine, when starting a long east-west road or air trip, is not to change my watch. If going west, against the rotation of Earth, the sun will set much later according to my watch. My watch must be set back (earlier) if I am headed west to compensate for the spherical Earth. If going north or south, the altitude of Polaris, also called the North Star, will change a degree for every degree of change that is made traveling north or south. The shadow of the Earth projected onto the moon during every lunar eclipse is always round. Since lunar eclipses occur in different parts of the sky, at different times of the year, and at different times of the night, the Earth must be spherical in shape. The shadow cast by a sphere must always be round.

MISCONCEPTION—HEAVIER (MORE MASSIVE) OBJECTS ACCELERATE FASTER THAN LIGHTER (LESS MASSIVE) OBJECTS:

TRUTH: The same formula $F = Gm_1m_2/r^2$ that was used to demonstrate the force of attraction between the Earth and the moon is the key to understanding this concept. A variant of that formula is $a = Gm_1/r^2$, where a = acceleration, G = the constant of gravity, m_1 = the mass of the attracting body, and r = the radius separating the two objects. Note that the mass of the falling object is not even taken into consideration in the calculation of its acceleration under the force of gravity. Neglecting air resistance, two objects of differing masses will accelerate at the same rate. Even though the force of attraction is directly related to the mass, so is the inertia, or resistance to change of the falling body. The two balance each other perfectly so that the rate of acceleration remains the same.

DEMONSTRATION: Take a dime and a quarter or half dollar and stand on a chair. Hold the two coins at the same height above the floor and drop them. They will strike the ground simultaneously. Galileo, purportedly, was the first to perform this experiment in 1590 by dropping weights of differing masses from the Leaning Tower of Pisa in Pisa, Italy.

THE MOON

MISCONCEPTION—THE PHASES OF THE MOON ARE CAUSED BY THE MOON GOING INTO AND OUT OF THE EARTH'S SHADOW:

TRUTH: The phases of the moon result from the revolution of the moon around the Earth, and our observations of the near hemisphere, cycling through a day and night sequence. Only during a lunar eclipse will the moon intersect the Earth's shadow. The transition from the uneclipsed moon to the eclipsed moon takes about one hour. The phase cycle of the moon occurs in approximately $29\text{-}^1/_2$ days.

TO DEMONSTRATE THE MOON'S PHASES, a light bulb (preferably clear) and a small ball attached to a stick are all that are necessary. In a darkened room, allow the light source to represent the sun, the ball to stand for the moon, and your head will become the Earth. Hold the moon in your left hand so that it is positioned between your eyes and the sun. You will notice the hemisphere facing you is in complete darkness. This is called the ***new moon.*** By revolving the moon in a counterclockwise direction around your head and observing the moon as it orbits, you will see the moon progress through the ***waxing crescent*** phase (less than half lit), ***first quarter*** phase (half on, half off, light to the right), the ***waxing gibbous*** phase (more than half lit—both limb and terminator appear

convex), and finally the ***full moon*** phase (the hemisphere facing Earth is totally illuminated). These phases will repeat themselves in reverse order (***waning gibbous, last or third quarter,*** and ***waning crescent*** moons) as the moon continues in its orbit around the Earth, eventually moving completely into its own shadow to renew the ***new moon*** phase.

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LUNAR PHASES WITH A "MOON ON A STICK"

Instructions: The room will be divided into teams, each containing two to three members. Each team will receive an envelope containing the eight major phases of the moon. Teams will order the moon in its correct phase cycle from either right to left or left to right starting with one of the black disks and ending with a black disk. If you are completing the exercise by yourself, make a copy of this page from the PDF version and cut out each moon to create the correct order of the lunar phases.

The picture below gives the phase disks which will be contained in your envelope.

Moon on a Stick: In this demonstration your head will become the Earth, your eyes, the location on the Earth, and a lit light bulb, the sun. A Styrofoam ball and a sharpened pencil are all you need to create your moon on a stick. A simplified demonstration of this laboratory exercise can be found here. To begin the phase demonstration, darken the room and start with the moon hiding the sun. Note that the hemisphere (side) of the moon facing you is in the moon's own shadow. It is dark. Begin to orbit the moon around your head in a counterclockwise direction with your eyes focused on the moon. You should be able to see a narrow fingernail-like sliver of reflected sunlight appearing. As the sliver becomes larger, more of the hemisphere of the moon facing you will be reflecting sunlight. When the moon appears half on and half off, light to the right, your head will be the vertex of a 90-degree angle between the moon and the sun. The moon has completed one quarter of its phases. Continue orbiting the moon around your Earth (head), and you will notice that more than half of the side of the moon facing you will be illuminated by the sun. It now looks as if the moon is bulging or convex on both sides. As the moon continues to orbit your Earth, more and more of the hemisphere facing you will be illuminated by the sun. Finally, the hemisphere of the moon facing you will be completely illuminated by the sun. As the moon continues to orbit around the Earth, the phases of the moon will appear to cycle in reverse order, and the amount of reflected sunlight will lessen until the hemisphere facing you is once again in complete darkness.
Finish the lunar phase demonstration as noted above. It should compare to the phase ordering which you constructed with the disks given to you in the envelope. Note the phases by using one or a combination of two words found in the word bank in the exercise to describe the phase.

Waxing: to grow or to become larger
Waning: to become smaller
Crescent: arc or horn-shaped like the sliver of a fingernail.
Gibbous: bulging on both sides or convex on both sides
Full: completed filled by sunlight
New: hemisphere of moon facing the Earth is half on and half off
Quarter: The moon is half on half off with its light either to the right (first) or left (last)

NOTES

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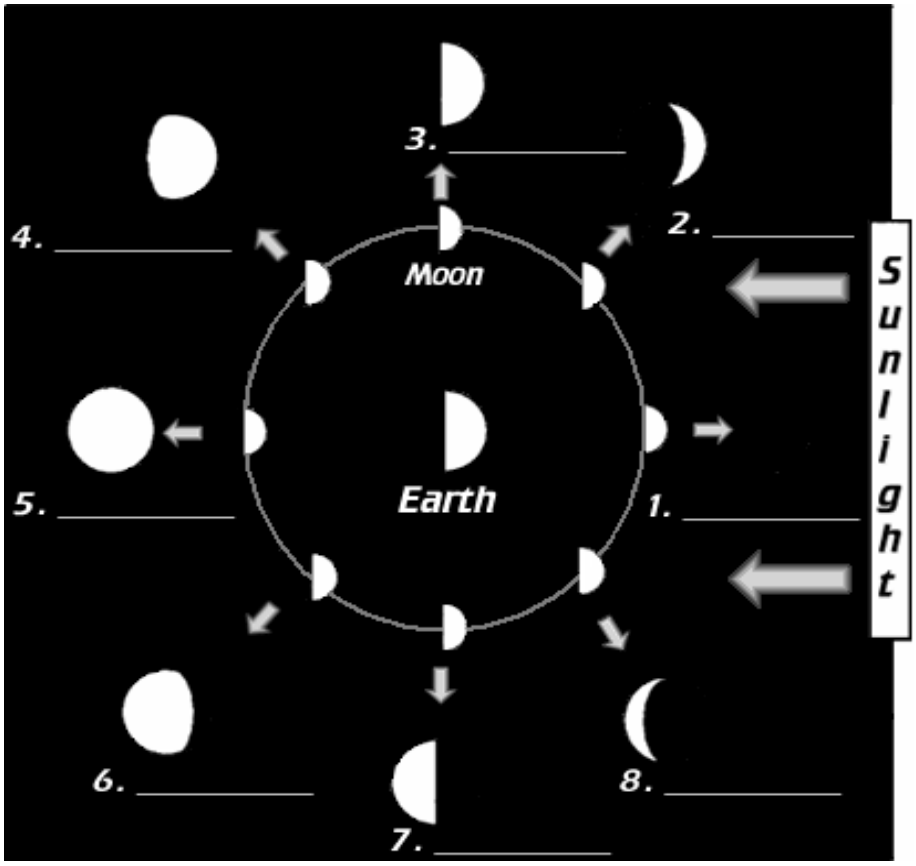
KNOW THE PHASES OF THE MOON (or Die)

(10 points—each error counts ½ point)

Each phase has two words.

1. _____ _____
2. _____ _____
3. _____ _____
4. _____ _____
5. _____ _____
6. _____ _____
7. _____ _____
8. _____ _____



Instructions: After completing the "Moon on a Stick" activity, label the phases of the moon as noted above. Answer the questions below the diagram and on page two.

Word Bank

revolution, third, full, new, quarter, first, last, night, waxing, waning, crescent, gibbous, terminator, day

9. _____ Is the moon waxing or waning? >1 but <5.
10. _____ Is the moon waxing or waning? >5 but < 8.
11. _____ General phase of the moon, gibbous or crescent, >3 but < 7, but not 5. What is the common phase word in each of the phase names?
12. _____ General phase of the moon, gibbous or crescent, >7 but < 3, but not 1. What is the common phase word in each of the phase names?
13. _____ The transition location on the moon where day changes into night.
14. The phases of the moon result from the moon's _____ around the Earth which allows us to witness its _____ and _____ cycle.

Remember that you always wax your car before it "wanes." Elizabeth O. Evans, Dieruff H. S., fall, 2007

15. _____ The moon receives its light from the … .

16. _____ The process by which the moon shines is called … .

17. _____ A horned moon is a … moon.

18. _____ A moon that **bulges** outward or is convex on **both sides** is called a … moon.

19. _____ With regards to the changing phases of the moon, to grow mean to ….

20. _____ A moon that is diminishing in the amount of light that is being reflected is called a … moon.

21. _____ Whether the moon is in a crescent or in a gibbous phase, when the light is to the right, the moon is **waxing or waning** (select one).

22. _____ Whether the moon is in a crescent or in a gibbous phase, when the light is to the left, the moon is **waxing or waning** (select one).

23. _____ If the terminator is a straight line, the moon is in a … phase.

24. _____ A first quarter moon is **waxing or waning** (select one).

25. _____ A last quarter moon is **waxing or waning** (select one).

26. _____ The phase of the moon during a total solar eclipse is … .

27. _____ The phase of the moon during a total lunar eclipse is … .

28. _____ **True or false** (select one) The moon has a "side" that never sees the sun.

29. _____ **True or false** (select one) There is a portion of the moon which we never see from the Earth.

30. _____ From your answer above, this part of the moon is called the … … .

31. _____ A new moon will rise and set about the same time as the … .

32. _____/_____ A full moon will rise and set about the same time that the sun … and … . The words must be in their correct order.

The general phases of the moon are composed of the following words: new, full, quarter, crescent, gibbous, waxing, waning, moon, first, last or third. Name the four phases of the moon which last only through the duration of one night and the other four phases which can occur over the course of many nights. **Each phase will have two words, i.e., new moon.**

33. One night _____, _____
_____, _____

34. Many nights _____, _____
_____, _____

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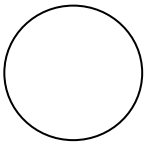
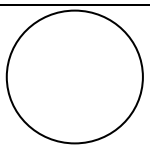
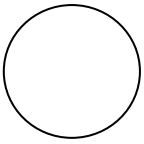
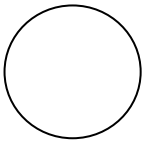
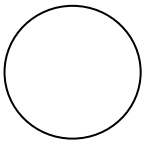
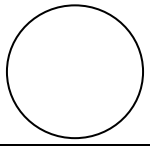
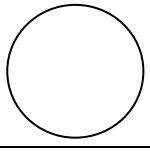
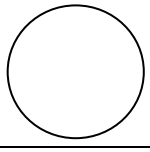
THE RHYTHM OF THE MOON'S PHASES

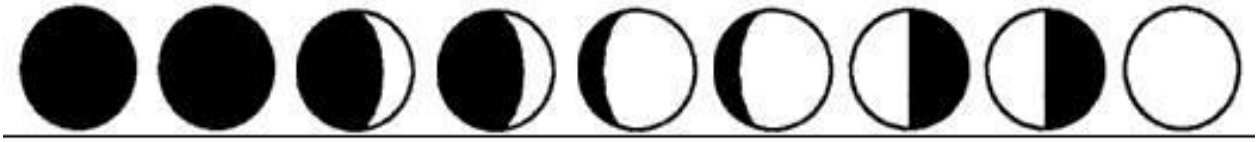
Instructions: Using a computer graphics program or a planetarium, examine the rising, setting, and transiting times of the moon at its four major phases: new moon, first quarter, full moon, and last quarter. Examine as well the mid-points between these phases: a four day, 11-day, 18-day, and a 26-day old moon. Compile this information in the table below to see if you can find a general relationship between the moon's rising and setting times. Use an average day with the sun above and below the horizons for a 12-hour period. You can use a 24-hour European clock or the American a.m., p.m., system, but remember there is no international agreement on the instant of noon and midnight having an a.m. or a p.m. designation, so simply use Noon and Midnight.

Lunar Phase	Phase Drawing	Rising Time	Transiting Time (on meridian)	Setting Time
New Moon				
Waxing Crescent				
First Quarter				
Waxing Gibbous				
Full Moon				
Waning Gibbous				
Last Quarter				
Waning Crescent				

NOTES

PHASES, ROTATION, DISTANCES, AND LIBRATIONS OF THE MOON

Lunar Phases: As we watch the moon go through its phases, we are witnessing the moon revolving around the Earth while it progresses through its day and night cycle (Memorize this fact). This cycle is equivalent to about one month and will be derived more precisely in the exercise that follows. As the moon changes its shape, there are seven phase words that are important: waxing, waning, crescent, gibbous, full, new, and quarter. Waxing means to grow; the light of the moon is on the right. Waning is when the moon is decreasing in brightness, and its illumination is on the left. Crescent means horned, like a croissant, and gibbous comes from the Latin, humped. With its two "b's" think about the moon **b**ulging outward on **b**oth sides. As we are viewing Luna in a gibbous phase, more than half of its surface is illuminated by the sun. When the moon is full, the hemisphere facing the Earth is completely filled with sunlight; it is opposite to the sun with the Earth between them. When the moon is new, it is in the same direction as the sun, and the hemisphere facing Earth is in complete darkness. The opposite hemisphere called the far side is in a full phase. This hemisphere has been mistakenly called the dark side of the moon even though all parts of the moon go through a day and night cycle. It is the quarter moon where some confusion arises because the moon appears to be half illuminated. A first quarter moon, half on—half off, is a waxing moon presenting the right half of its disk in sunlight. The dividing line between day and night, the terminator is a straight line. The moon has completed the first quarter of its phase cycle, and hence, it is called a first quarter moon. At last quarter, half on—half off, it is the left half of the waning moon that is observed. A last quarter moon has proceeded through three-quarters of its phase cycle and can also be called a third quarter moon. I prefer last quarter since the **l**ight of a **l**ast quarter moon is on the **l**eft (the three L's). Sometimes students will refer to a full moon as the second quarter, but this term is not accepted by anyone. With your lunar phase vocabulary refreshed, at your first opportunity, watch Luna progressing from a thin waxing crescent to a first quarter moon. It will still be only about 10 percent as bright as a full moon. Examine as Luna changes its position in the sky as it revolves around the Earth. The big change in the moon's brilliance explodes during the three days following first quarter and culminates in the full moon which is bright enough for some individuals to see color or read a newspaper by its light. Can you put the following phases of the moon in their correct order? See "The Moon on a Stick" exercise.



The Harvest Moon and other Moon Names: The moon that is closest to the autumnal equinox is called the Harvest Moon. It is at this time of the year that the moon's orbital path is closest to being parallel with the eastern horizon. Accordingly, the moon's orbital motion around the Earth does not carry it very far below the horizon during the course of a day. For several nights the nearly full moon rises well before twilight ends. Before electric lights, farmers in Europe and America could continue harvesting their crops well into the night. The term "Harvest Moon" first originated in Europe where the change in time between moonrises near its full phase was only 10-20 minutes around the autumnal equinox. At our latitude of 40 degrees north, the change is 25-30 minutes on average. You may be surprised to learn that the full moons of other months also have names. Here they are: **January**—Old Moon, or Moon After Yule; **February**—Snow Moon, Hunger Moon, or Wolf Moon; **March**—Sap Moon, Crow Moon, or Lenten Moon; **April**—Grass

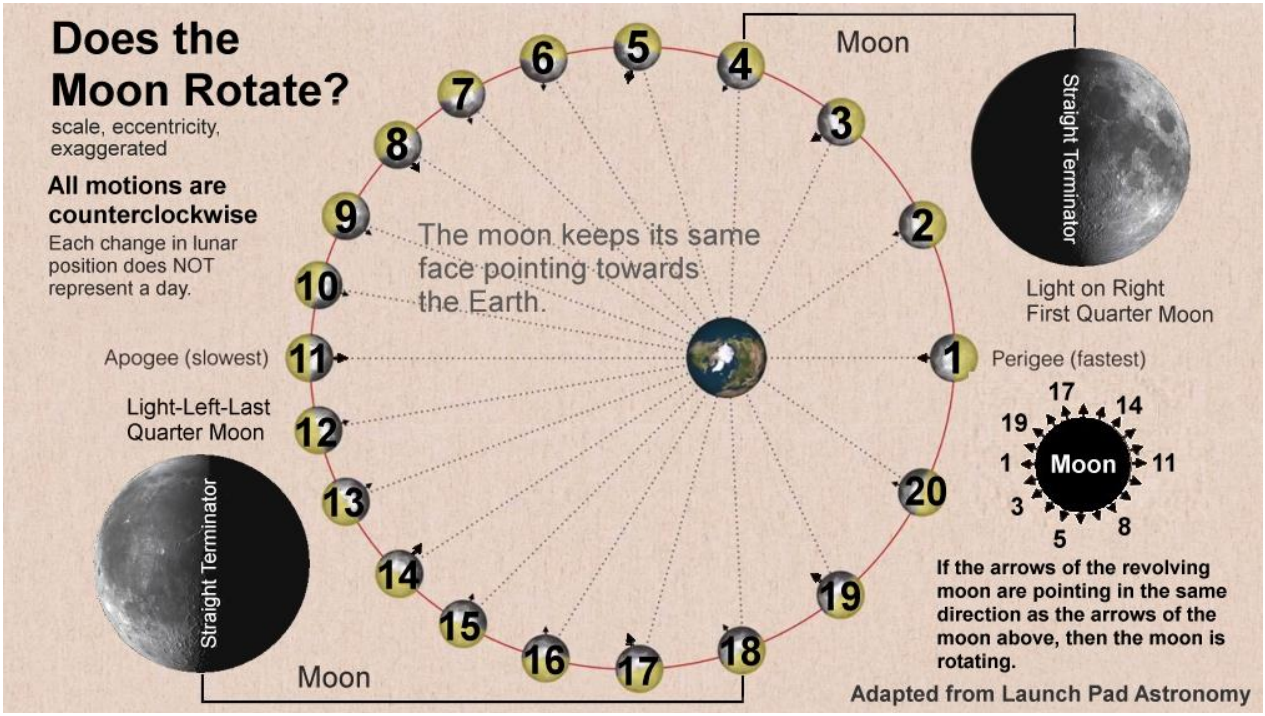
Moon or Egg Moon; **May**—Planting Moon or Milk Moon; **June**—Rose Moon, Flower Moon, or Strawberry Moon; **July**—Thunder Moon or Hay Moon; **August**—Green Corn Moon or Grain Moon; **September**—Harvest Moon or Fruit Moon; **October**—Hunter's Moon; **November**—Frosty Moon or Beaver Moon; **December**—Moon Before Yule or Long Night Moon. The next time the moon is full, you may see it in a new light or at least call it by its rightful name.

Summersaulting Moon: When the moon is full or near its full phase, try this little experiment. It will require you to view the moon shortly after it rises in the east, and then again near its setting location, around dawn or around bedtime—midnight to 1:00 a.m. The observations need not occur on the same night, but they should take place around the time of the full moon, which makes this phenomenon easier to detect. Notice the maria, the dark, waterless regions where most of the lunar landings took place. At moonrise they will appear to be pointed upward; by midnight, they will be more horizontal; and by moonset they are slanted downward. This curious movement is not a motion at all, but merely a consequence of Earth's rotation carrying astronomical bodies across an arcuate (curved) path in the sky. Understand the tilt of the moon, and you will come to realize that most movie footage of the moon is taken in the early evening, even if the scene is supposed to be occurring in the early hours of the morning. Constellations follow the same convention as the American poet Robert Frost noted in the "Star-Splitter." "You know Orion always comes up sideways. Throwing a leg up over our fence of mountains…" When Orion sets, it's like he has just tripped and is falling face forward against the Earth—splat! If you didn't catch it, that last sentence was not Frost's.

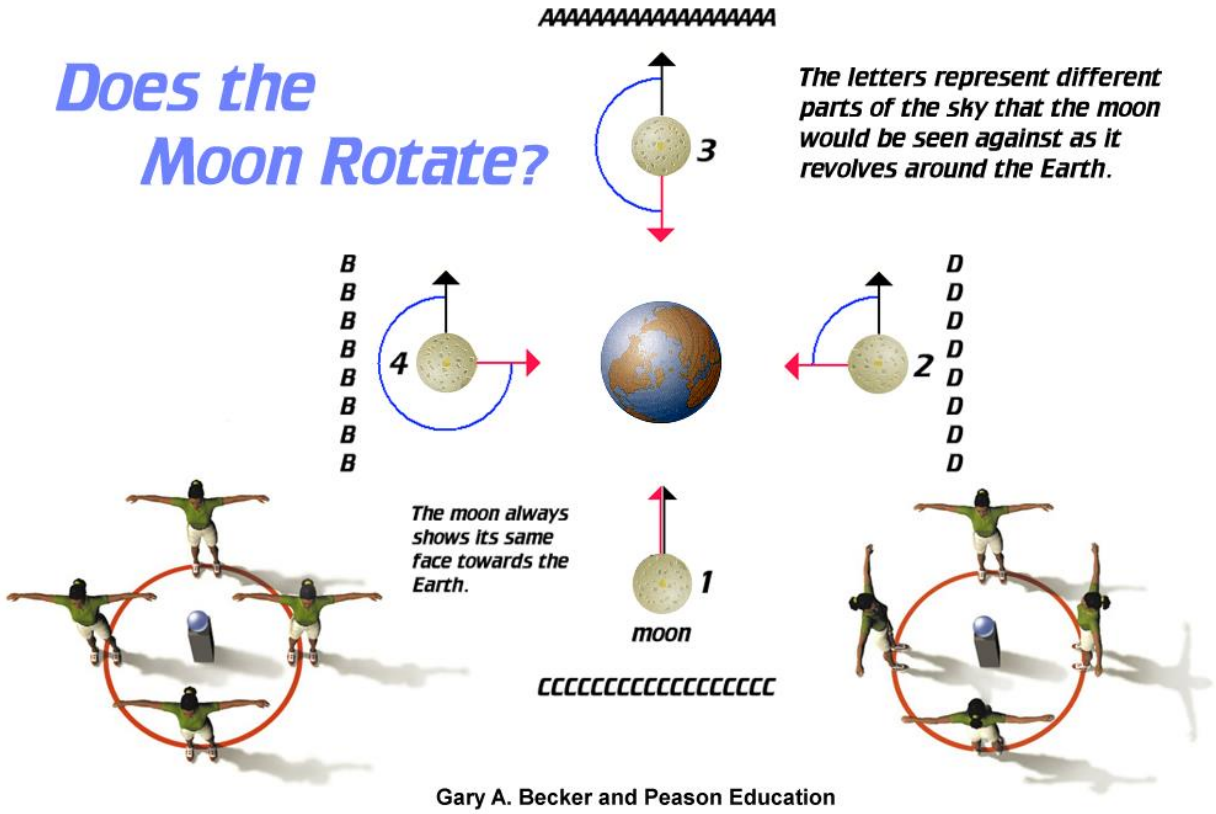
***MISCONCEPTION*—**THE MOON DOES NOT ROTATE:
TRUTH: The moon completes exactly one rotation about its axis in the same period of time that it takes to complete one revolution around the Earth. This period is equal to 27 $^{1}/_{3}$ days. It is only because of the synchronous motion of rotation and revolution that we observe the same hemisphere of the moon always facing us.
DEMONSTRATION-1: To illustrate this concept, orbit around a person with your face looking in the direction of that person and one hand extended toward the person at all times. As you revolve around your partner, you will notice your arm also making a complete sweep around the room during the same interval of time that it takes to make one revolution. By remaining in the same location and completing one rotation, the room will also appear to sweep around you in the same manner as before. ***This conclusively proves that the moon does rotate***. If the moon did not rotate, then your hand would always point in the same direction as you revolved around your partner. At first, your face might be visible, but in a half revolution your back would now be observed. If the moon did not rotate, all locations on the lunar surface would face the Earth during the time period of one revolution and the concept of a dark side or unknown region of the moon would never have originated.
DEMONSTRATION-2: This illustration was the result of an insightful question which was asked at a 2008 in-service program at the ASD Planetarium about the tilt of the moon's axis. A rotating Earth globe with a long wooden dowel which represented its axis, was substituted for the moon. The lunar axis, similar to Earth's axis, is tilted (only by about six degrees to its orbital plane) and points in the same direction. With the lunar axis pointing in the same direction, the only way it is possible to keep the same lunar hemisphere pointed towards Earth is if the globe representing the moon rotates.
DEMONSTRATION-3: Here is another very effective way of authenticating the rotation of the moon. Drill holes at the poles of a moon globe through which a wooden dowel can be inserted to

act as a visible axis. A smaller hole should be drilled at right angles to the axis through which a paper clip or other smaller rod can be inserted or glued. This will allow the globe to rotate freely around its axis. At the North Pole a large arrow should be fastened to the axial rod so that it is perpendicular to the axis and rotates with the axis. At the equator secure an eye screw though which a string can be fastened. Loosely tie the other end of the string to a post or have someone hold it. Use both hands to grasp firmly the globe by its axis. Revolve the globe around the strut keeping the string taunt. This will ensure the same face of the moon globe is always pointing towards the strut. Keeping the arrow always pointing in the same direction, it is a no brainer to see that the globe is rotating underneath the arrow. Like the moon, the globe will always keep its same face pointed towards the center and complete one rotation (spin) in the same time period that it takes to make one complete revolution (orbit).

Rotation of the Moon: The moon keeps its same face pointing towards the Earth at all times. This means that the moon does or does not rotate on its axis? Think about this. Examine the following picture. Note the numbers associated with the moon in its orbital path and with the smaller circle on the right with the many arrows pointing from it. The same numbers and arrow directions on the moon wheel correspond to the numbers on the moon's orbital path around the Earth. If the object makes a complete spin then the moon rotates.
Does the moon rotate? Yes or No. Circle the answer which you believe to be correct after examining the two pictures which follow this exercise.

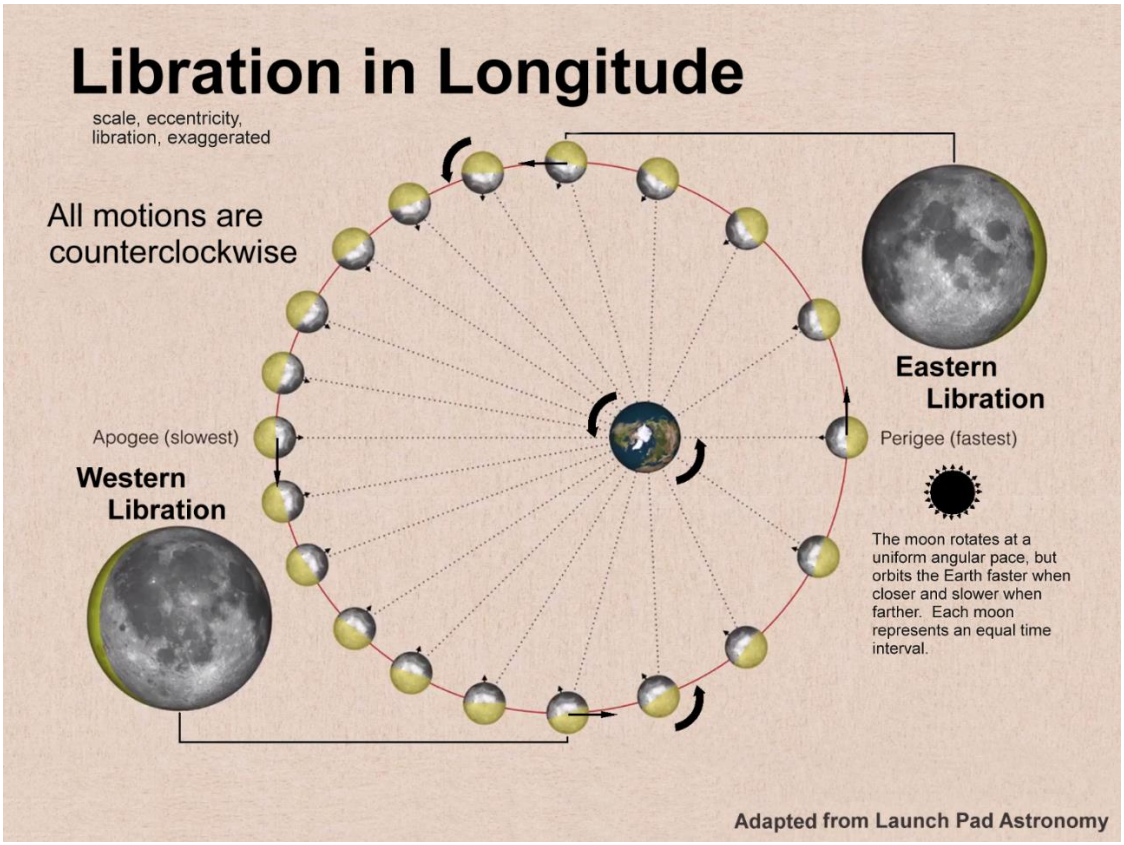


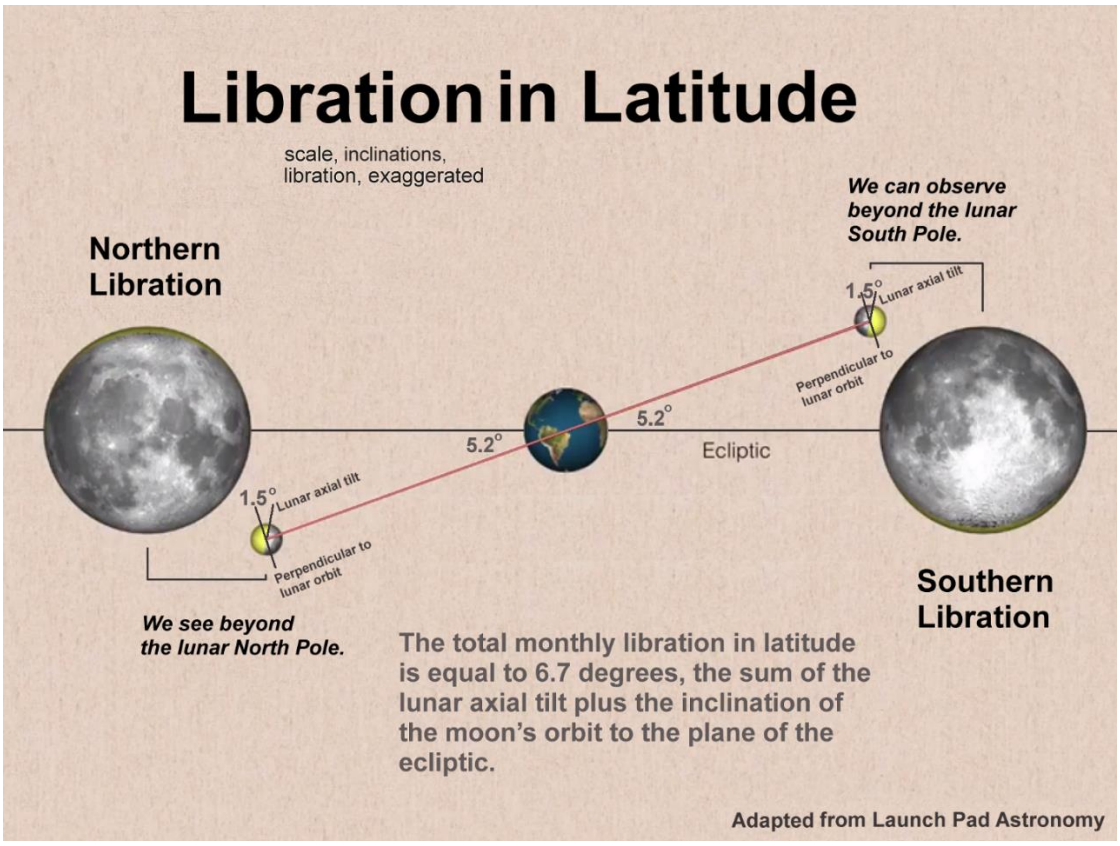
Here is another way of looking at whether the moon rotates. In the slide, position marked one, the observer looks in the direction of AAAAAAA. In position two he/she looks in the direction of BBBBBBB, etc. If the moon keeps its same face or hemisphere pointed towards the Earth, then it must complete one spin on its axis. Does the moon rotate?



Lunar Librations: I had a rough night's sleep. When counting asteroids and melatonin didn't work, my wife asked what was bothering me. I said, Lunar librations… I'm trying to visualize them in my mind." Her response was, "Why are you just picturing them? Place an order at the State Store." "Not libations," I responded, becoming even more alert, "librations, the wobbling effects that the moon goes through as it orbits the Earth." "Can't help you there," she responded, falling back to sleep. There are three of them, two in longitude (east-west) and one in latitude (north-south). Over a 30-year period, they allow astronomers to view 59 percent of the lunar surface, not just the normal 50 percent that most individuals believe can be observed. The never before seen 41 percent of the far side of the moon was first imaged by the former Soviet Union's Luna 3 in 1959. The moon keeps its same face pointing towards Earth, a synchronous dance that allows Luna to complete one rotation (spin) in exactly the same interval of time that it needs to complete one revolution (orbit) around the Earth. The moon's rotation takes place at a uniform (angular) rate. While the moon is acting very consistent in its rotation, it is also revolving around the Earth in an elliptically-shaped (oval) orbit, moving towards and away from our planet, continually changing its orbital speed. When the moon is nearest at perigee and farthest at apogee, Luna basically has no longitudinal librations. At perigee the moon is orbiting at its greatest velocity. As the moon begins to move away from perigee, Luna's angular change due to rotation lags behind the more rapid angular change due to its orbital motion, and we get to peek around the eastern limb of the moon. By the time the moon reaches apogee, its farthest distance from Earth, we see it face on again with no libration in longitude. Here the moon is moving at its slowest

orbital motion, but it continues to rotate at an even angular rate slowly outpacing its orbital motion. We now get to peek around the western limb (side) of the moon. Another smaller diurnal (daily) libration in longitude is at its maximum when the moon rises and sets. When Luna rises, our terrestrial position is "higher" than the moon's location, and we get a little peek over the eastern boundary, similar to being on the summit of a high mountain and being able to look over the curvature of the Earth. Likewise, when the moon sets, we look a little beyond its western limb. Those are the two geometrical librations in longitude, but what about the libration in latitude which is a north-south oscillation? The moon's axis which always points in the same direction as it orbits the Earth is tilted about 1.5 degrees to the perpendicular of its orbital plane, but the plane of the moon's orbit is also tilted by about 5.2 degrees to the plane of Earth's orbit (the ecliptic), causing the moon to have a total tilt of about 6.7 degrees in latitude as viewed from the Earth. Again, think of yourself being on a mountain. When the moon is located below the ecliptic, we have a view beyond the lunar north pole, but when the moon is above the ecliptic, we now get a peek past the lunar south pole. Keep in mind that while these librations are occurring the moon is moving closer and farther from the Earth as well as above and below the ecliptic plane, exaggerating the wobbling motions. Here is are links to many years' worth of lunar librations compiled by NASA's Lunar Reconnaissance Orbiter, https://astronomy.org/moravian/index.html#6. Two images modified from ***Launch Pad Astronomy's*** video on eclipses (below), should help explain the major lunar librations in a more visual sense. Having now been able to envision these three librations in my mind and write descriptively about them, I feel the need to celebrate, taking my wife's advice, with a libation. Cheers!




Libration in Latitude
scale, inclinations, libration, exaggerated
Northern Libration
We can observe beyond the lunar South Pole.
1.5°
Lunar axial tilt
Perpendicular to lunar orbit
5.2°
5.2°
Ecliptic
1.5°
Lunar axial tilt
Perpendicular to lunar orbit
We see beyond the lunar North Pole.
Southern Libration
The total monthly libration in latitude is equal to 6.7 degrees, the sum of the lunar axial tilt plus the inclination of the moon's orbit to the plane of the ecliptic.
Adapted from Launch Pad Astronomy

NOTES

Name _____ Date_____ Moravian University

SYNODIC, SIDEREAL, AND ANOMALISTIC LUNAR PERIODS
(Phase, Orbit, and Distance)

Introduction: Examine the PowerPoint on lunar phases found here, https://astronomy.org/moravian/C02-Misconceptions.pdf and go to the slides which show the moon progressing through an 99-day and a 110-day sequence of phases, librations, and distances. From these slides and a YouTube video found in the same section, you will be able to gain a better appreciation for the:

1. **Phase Period of the Moon:** This is called the synodic period, the time it takes the moon to complete a full series of phases, important for the time period of the month, how early humans established calendars, and the prediction of eclipses and their saros cycles.
2. **Orbital Period of the Moon around the Earth:** This is termed the sidereal period and can be determined by the moon's passage by the First Point of Aries, a reference position in the sky.
3. **Perigee to Perigee and Apogee and Apogee Periods of the Moon:** Called the anomalistic month, it is the time it takes the moon to travel from closest to closest positions to the Earth (perigee to perigee) and farthest to farthest positions from the Earth (apogee to apogee).

Procedure for Determining the Synodic (phase) Period of the Moon:

1. **The major phases of the moon**—New Moon, First Quarter, Full Moon, and Last Quarter are shown at the end of this laboratory exercise.
2. In the 99 and 110-slide PowerPoint sequences found in the *Popular Misconceptions* section, https://astronomy.org/moravian/C02-Misconceptions.pdf, determine the day of the New Moon, First Quarter, Full Moon, and Last Quarter moons. The day counts are indicated in the upper left of each slide.
3. Proceed through all of the slides in the Misconceptions PowerPoint and list the days when these phases occurred in the first table.
4. State the interval of time between the repetition of like major phases as well as the average length of time for each phase type in the left column. Keep in mind each picture represents the phase of the moon at 12:01 a.m., whether the moon was visible or not from Bethlehem, PA. Note that the phase series composed of 99 slides was completed near Earth aphelion (farthest position to the sun), while the second series of 110 slides was completed near Earth perihelion (closest location to the sun).

Additional Recommendations: Watch the YouTube videos on lunar phases at https://astronomy.org/moravian/C02-Misconceptions.pdf, then complete the exercise "Know the Phases of the Moon or Die" in the "Misconceptions" chapter. Submit this to your instructor for a grade. Take the lunar phase practice quiz https://astronomy.org/moravian/C02-Misconceptions.pdf. Know the phase that comes before and after the one that is pictured in the sample quiz.

PHASE PERIOD OF THE MOON

This phase series was completed near aphelion, when Earth's orbital speed was slowest.

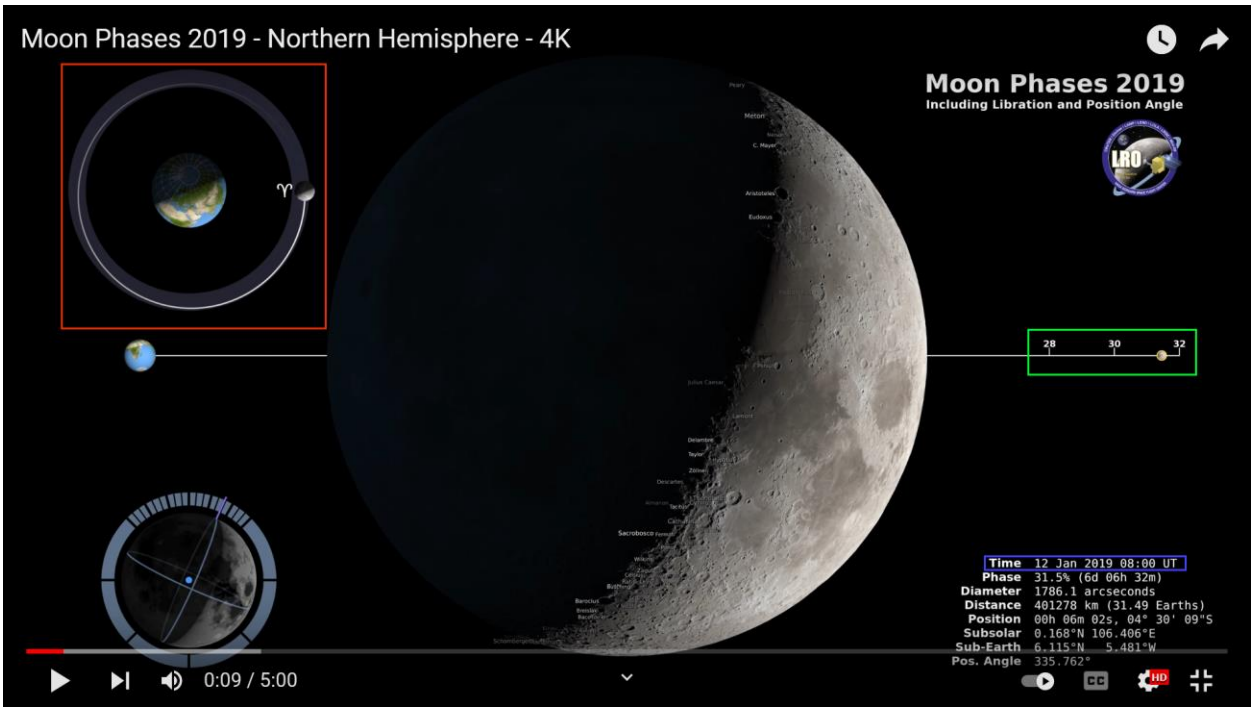
Lunar Phase **Completed near Earth Aphelion (Earth farthest from the sun)**	**Day**	**Days Between Similar Phases**	**Day** Arrow: move same number from top to bottom.	**Days Between Similar Phases**	**Day** Arrow: move same number from top to bottom.	**Average No. of Days Between Similar Phases**
New Moon	7					
First Quarter						
Full Moon						
Last Quarter						
New Moon						
Average of All Averages	----- -----	---------- ----------	----- -----	---------- ----------	----- -----	

This phase series was completed near perihelion, when Earth's orbital speed was at its greatest.

Lunar Phase **Completed near Earth Perihelion (Earth closest to the sun)**	**Day**	**Days Between Similar Phases**	**Day** Arrow: move same number from top to bottom.	**Days Between Similar Phases**	**Day** Arrow: move same number from top to bottom.	**Average No. of Days Between Similar Phases**
New Moon						
First Quarter						
Full Moon						
Last Quarter	135					
New Moon						
Average of All Averages	----- -----	---------- ----------	----- -----	---------- ----------	----- -----	

<u>Orbital (Sidereal) Period of the Moon</u>: In this exercise we are going to use NASA's ***L**unar **R**econnaissance **O**rbiter* data to determine the orbital period of the moon around the Earth. You can go to https://astronomy.org/moravian/index.html#6 to find the necessary YouTube videos of LRO data. On the following picture, the red box (upper left) marks the orbital period of the moon. Luna is next to the first point of Aries ♈, the location of the sun on the first day of spring (Vernal Equinox). That will be your reference point for determining how long the moon takes to orbit the Earth. Stop the video and note only the day of this passage. That datum can be found in the lower right-hand part of the video noted in the blue rectangle. Start in January and

complete the passages of the moon past the First Point of Aries for that year. Find the number of days between each passage and take the average of those day for each row. Take the last column and average all of the averages for that column and place your answer in the bottom right box. You may pick any **L**unar ***R****econnaissance* ***O****rbiter* year you choose,



1. **<u>Here are the number of days each month contains:</u>**
   J-31, F-28 (29 in 2016 and 2020), M-31, A-30, M-31, J-30, J-31, A-31, S-30, O-31, N-30, D-31
2. **<u>Arithmetic</u>:** What are the number of days between April 4 and May 27? Find the difference between the remaining days in April by subtracting 4 from 30 than adding the number of days in May. 30 – 4 = 26 + 27 = 53. There are 53 days between April 4 and May 27.

PERIOD OF REVOLUTION OF THE MOON AROUND EARTH

♈	Day	Difference in Days	Day	Difference in Days	Day	Difference in Days	Day	Average In Days
Passing the First Point of Aries ♈	**Jan.**		**Feb.**		**Mar.**		**Apr.**	
Passing the First Point of Aries ♈	**Apr.**		**May 1**		**May.**		**Jun.**	
Passing the First Point of Aries ♈	**Jun.**		**Jul.**		**Aug.**		**Sept.**	
Passing the First Point of Aries ♈	**Sept.**		**Oct.**		**Nov.**		**Dec.**	
Average	------	------	-----	------	------	------	------	

Procedure for Calculating the Anomalistic Period of the Moon:

The moon revolves around the Earth in an elliptical orbit getter closer and farther from Earth. The time it takes the moon to orbit the Earth from its closest position, perigee to the next perigee, or from its farthest location, apogee to the next apogee, is called the anomalistic period. It is an important interval related to the prediction of similar solar eclipses. Its period may surprise you.

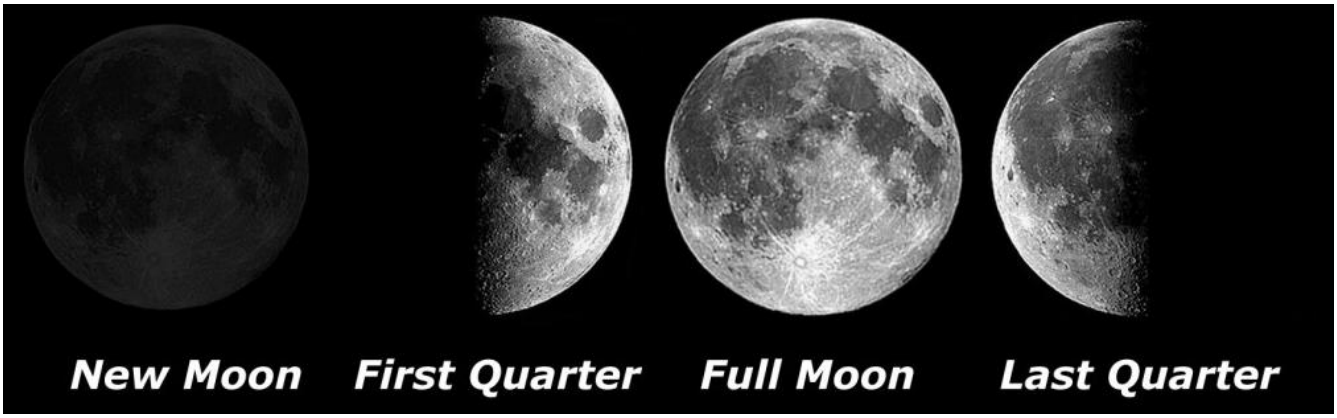
1. By scrolling through the PowerPoint slides rapidly, or better yet watching one of the ***L**unar **R**econnaissance **O**rbiter videos* you will see the changing angular diameter (size) of the moon in the sky, a function of the moon's changing distance from the Earth.
2. Go to https://astronomy.org/moravian/index.html#6 and use one of the compilations created by NASA's Lunar Reconnaissance Orbiter. You will get the most accurate results if you incorporate the difference in time between events, including the fraction of a day between perigees (largest moon) or apogees (smallest moon). **Your instructor will tell you whether he wants you to achieve this better accuracy or simply a day count.**
3. Note in the table when the moon will be at its perigee position, closest to Earth and largest in the sky and at its apogee location, farthest from Earth and smallest in the sky. You can accomplish this by observing the movement of the small ball located at the right center of the screen marked by the green rectangle in the picture found on the previous page. The ball will move between the numbers 28 and 32. Those number represent the moon's distance in Earth diameters. Earth is approximately 8000 miles in diameter.
4. At the point of largest or smallest lunar size, stop the video and note the month and the day. **Only indicate the hour if your professor requests this additional information.**
5. Calculate the days between perigee to the next perigee and apogee to the next apogee.
6. Take the average of your findings to discover the perigee to perigee and apogee to apogee time intervals more accurately. Place these in the last column. Finally, take the average of all periods in the last column and place your answer at the bottom right of the table.
7. **Hints:** Maximize your screen brightness. Slow the video down and increase the resolution of the image in the settings section. You can go as high as 4K. Observe the ball moving back and forth (center right of your screen—green rectangle) giving the Earth-moon distance in Earth diameters.
8. **Here are the number of days each month contains:**
   J-31, F-28 (29 in 2016 and 2020), M-31, A-30, M-31, J-30, J-31, A-31, S-30, O-31, N-30, D-31
9. **Arithmetic:** What are the number of days between July 27 and August 23? Find the difference between the remaining days in July by subtracting 27 from 31 than add the number of days in August. 31 – 27 = 4 + 23 = 27. There are 27 days between July 27 and August 23.

   Use this method if your teacher asks you to include the day plus hour counts.
10. **Arithmetic:** Find the difference in time between May 15, 05 hours and June 10, 17 hours. May has 31 days or 30 days, 24 hours.
    (May) 30 days, 24 hours – (May) 15 days, 05 hours = 15 days, 19 hours + (June) 10 days 17 hours = 25 days 36 hours = 26 days 12 hours, or 26 days + 12/24 day = 26.5 days. To decimalize your answer, please see below. Got it, Good!
11. **Decimalize the day in the DIFFERENCE Columns to the nearest 1/10 of a day:** If the final difference between two perigee or apogee positions comes to 28-14/24 days, the 14/24 is equivalent to 0.58 day which would round up to 0.6 day or 28.6 days for your final answer. Divide the 24 into the 14 to get this fraction then round up.

ANOMALISTIC PERIOD OF THE MOON
(day count or days plus hours)

	Day/Hr.	Difference Days/Hr.	Day/Hr.	Difference	Day/Hr.	Difference Days/Hr.	Day/Hr.	Average Days/Hr.
Perigee Moon Largest	**Jan.** hours	Decimalize Days	**Feb.** hours	Decimalize Days	**Mar.** hours	Decimalize Days	**Apr.** hour	
	Apr. hours	Decimalize Days	**May** hours	Decimalize Days	**Jun.** hours	Decimalize Days	**Jul.** hour	
	Jul. hours	Decimalize Days	**Aug.** hours	Decimalize Days	**Sept.** hours	Decimalize Days	**Oct.** hour	
	Oct. hours	Decimalize Days	**Nov.** hours	Decimalize Days	**Dec.** hours	----------	----------	
Apogee Moon Smallest	**Jan.** hours	Decimalize Days	**Feb**. hours	Decimalize Days	**Mar.** hours	Decimalize Days	**Apr.** hours	
	Apr. hours	Decimalize Days	**May** hours	Decimalize Days	**Jun.** hours	Decimalize Days	**Jul.** hours	
	Jul. hours	Decimalize Days	**Aug.** hours	Decimalize Days	**Sept.** hours	Decimalize Days	**Oct.** hours	
	Oct. hours	Decimalize Days	**Nov.** hours	Decimalize Days	**Dec.** hours	----------	----------	
Super Average	**-----**	**----------**	**-----**	**----------**	**-----**	**----------**	**-----**	

MAJOR PHASES OF THE MOON



January 27, 2023

MISCONCEPTION—THE MOON HAS A HEMISPHERE IN PERPETUAL DARKNESS CALLED THE DARK SIDE:
TRUTH: Nothing could be further from the truth, but the term probably originated from the fact that we had little information about the hemisphere facing away from us. The moon has a portion of its surface (41%) that is never visible to earthbound observers, but all places on the moon experience a day and night cycle. When the moon is new and the hemisphere facing us is not illuminated, the other hemisphere is in full illumination. A better term for the hemisphere not visible from Earth would be the moon's *far side*.

MISCONCEPTION—THE MOON REQUIRES 28 DAYS TO COMPLETE ONE PHASE PERIOD, AS WELL AS ONE PERIOD OF REVOLUTION AROUND THE EARTH:
TRUTH: The moon's orbital period or ***sidereal period*** is 27 $^1/_3$ days, while the time the moon takes to complete a cycle of phases, is its ***synodic period,*** 29 $^1/_2$ days. The discrepancy arises because as the moon revolves around the Earth, the Earth is also revolving around the sun. In one revolution of the moon (27 $^1/_3$ days), the Earth has moved about 27 degrees in its orbit around the sun. While the moon has completed one orbit of Earth, it is no longer in the same phase orientation. It will take the moon an extra 2 $^1/_6$ days of orbital motion on average to align itself in the same manner to be able to repeat the same phase. Therefore, a lunar phase period equals 27 $^1/_3$ days, plus 2 $^1/_6$ days, or about 29 $^1/_2$ days, on the average. Rather than compromising between these two periods as most educators continue to do, it is better to emphasize the lunar phase period of 29 $^1/_2$ days. This is what we observe in the sky as we watch the moon cycling through its phases, and it is the major "beat" in the rhythmic cycle of predicting eclipses. Solar eclipses can only occur when the moon is new, while lunar eclipses can only happen at the time of a full moon. The etymology of the word month is from the Middle English. In Old English word for month was *mōnath.* The Old English word for the moon was *mōna*. The relationship should be obvious.

MISCONCEPTION—THE MOON HAS NO GRAVITY:
TRUTH: Any object which possesses mass (matter) has the force of gravity as a condition of its being. That goes for all matter: cars, baseballs, battleships, the moon, sun, planets, and all other objects found everywhere, regardless of whether they are large or small in volume. The force of attraction felt by one object for another is directly proportional to the product of their masses and inversely proportional to the square of the distance to which they are separated. Isaac Newton put it this way: the force of attraction between two objects, F, is equal to $G\ m_1\ m_2/r^2$, where G represents the universal constant of gravity; m_1 and m_2, the respective masses of the two attracting bodies; and r^2, the square of the distance between the centers of the two bodies. When comparing the acceleration of a less massive object, m_2, at the surface of a more massive body, m_1, the equation simplifies itself to $a = m_1/r^2$ because…
$F = m_2\ a$ and $F = Gm_1\ m_2/r^2$ therefore, $m_2\ a = Gm_1\ m_2/r^2$ or $a = Gm_1/r^2$

To show the relative attraction or acceleration at the moon's surface in relation to the Earth's surface, substitute the relative mass of the moon and the relative radius of the moon in Earth units in the equation $a = Gm_1/r^2$. Since G is a constant which equates F in specific units of measurement, it is no longer needed to solve the problem. Keep in mind that the answer will be in relative units of Earth's acceleration at the surface of m_1.

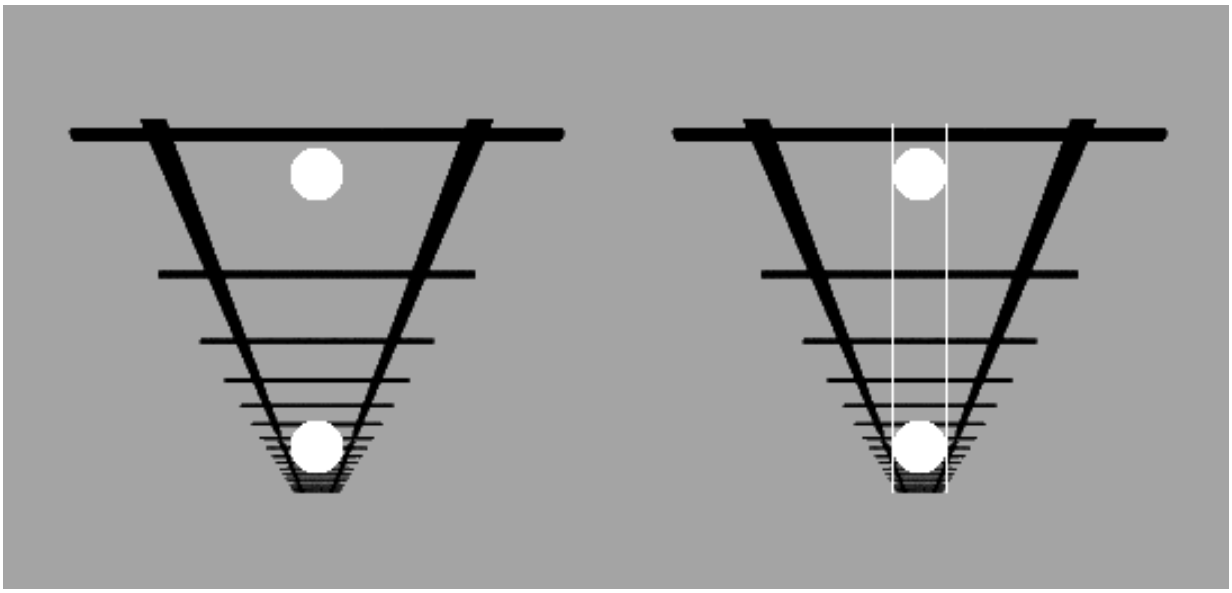
The mass of the moon is 0.0123 of Earth's mass, while the radius of the moon is 0.272 of Earth's radius. The acceleration of an object at the surface of the moon is $0.0123/(0.272)^2 = 0.166$, or about 1/6th that of Earth. The moon attracts objects at its surface with a force of 1/6 of Earth's

gravity. Therefore, the moon definitely has a gravitational field which is noticeable when an astronaut performs activities on its surface.

LUNAR LYMPICS: Here is a superb way of combining astronomy, mathematics, and athletic prowess all into one game of several fast-paced lessons with everybody looking like a winner. Sponsor an athletic competition with events comprised of throwing or kicking balls and calculate their lunar equivalents if the games were held on the moon. Measure the straight-line ground distance from where the event initiated (the ball was thrown) to where it landed. Multiply this number by six for the moon. If some estimate of height can be made, this number can generally be multiplied by six also. Other interesting competitions are the broad jump or the running broad jump, as well as a contest to see how high a student can leap from a standing position. In the latter case, measurements should be made from the tops of the students' heads, since they have a tendency to lift their feet in the jumping process. Beware of Frisbee and high jump contests, for they will not give accurate results when translated into the lunar environment. Air currents will affect the path of a Frisbee, and, of course, the moon has no atmosphere. In the high jump, the individual may elevate himself or herself five or six feet before clearing the bar. This does not accurately reflect the true height that the person has been lifted off the ground. It is the elevation of the center of mass, the balance point of the various parts of the body that is of concern. The center of mass for the human body corresponds to the pelvic area which is already elevated about two and a half to three and a half feet above the ground for an adult. When a successful jump is made, the athlete clears the bar in a horizontal position, lifting his or her center of mass from the three foot level to just slightly above the height of the bar. If the bar was at the six foot level, and an athlete had his or her center of mass at three feet, the lunar equivalent would place the bar at 21 feet, not at 36 feet, as might be expected from the other examples—(3 feet x 6) + 3 feet = 21 feet. Mrs. Ruth Erie of Ritter Elementary provided the inspiration behind this idea.

***MISCONCEPTION*—**THE MOON APPEARS LARGER ON THE HORIZON THAN WHEN IT IS HIGH IN THE SKY:

TRUTH: This is called the moon illusion, and it is a perceptual difficulty not based upon any measurable clues. The same illusion can be created on a two-dimensional surface as seen in the drawing below. According to the intuitive brain, the moon on the horizon is considered to be more distant than the moon that appears high in the sky. . The analytical brain interpreted through the eyes knows that the moon on the horizon or the moon high in the sky is the same angular diameter. The brain accepts that the moon near to the horizon which is perceived to be farther away must therefore appear larger than the moon high in the sky. The moon illusion is most likely not created by comparing the moon against a background of objects which appear smaller, but which the brain knows would appear larger if these objects were placed closer.



An inverted Ponzo illusion shows the moon illusion. All four moons are the same size, yet on the left, the lower moon nearer to the horizon appears larger than the higher moon.

DEMONSTRATION: Use a dime which is about the same angular diameter as the full moon when held at arm's length to prove the fallacy of this misconception. Hold a dime at arm's length and cover the moon when it is in a rising position. Repeat the experiment several hours later when the moon has moved to a much higher position above the horizon. It will be obvious that the moon has maintained its same apparent size in the sky.

MISCONCEPTION—THE BLUE MOON IS REALLY BLUE:
TRUTH: The blue moon is not blue at all since the light which we see reflected from its surface is only sunlight. Astronomically speaking, the blue moon is really the second full moon which can occur during a month's time. Since the phase cycle of the moon is 29 $^1/_2$ days, and a month has normally 30 or 31 days, blue moons occur very infrequently, about once every two to three years. The astronomical definition for the blue moon has its origins firmly rooted in the twentieth century. It appears as if our love affair with blue moons began as a mistake, over a half century ago in ***Sky and Telescope*** magazine. The use of the blue moon was traced to the 1937 edition of the ***Maine Farmers' Almanac***. However, in that year, the blue moon date occurred on August 22, clearly not the second full moon of the month, since it takes 29 ½ days for the moon to complete its cycle of phases. What had happened? The ***Maine Farmers' Almanac*** used a seasonal scheme for determining blue moons based upon a uniformly moving sun which made the seasons of equal length and occurring on fixed dates. There were normally three full moons for each season, and each of these moons was given a name. In 1937 summer full moons occurred on June 23 (after the summer solstice), July 23, August 21 (different from almanac), and September 20 (before the autumnal equinox). When a season contained four full moons, the rule was to designate the third full moon of that particular season as the blue moon. This allowed the other three named full moons to occur in better step with the seasons. In other words, the blue moon to the ***Maine Farmers' Almanac*** acted as a sort of "leap moon" to reset the seasonal calendar back into step with the full moon cycle. The blue moon, as we use it today, resulted from an interpretative error based upon a July 1943 ***Sky and Telescope*** article which referenced the 1937 ***Maine Farmers' Almanac***. The birthing of the blue moon as the second full

moon of a month was in March of 1946 also in ***Sky and Telescope*** magazine**.** The idea stuck and a new definition was born.

MISCONCEPTION—THE MOON APPEARS BRIGHT IN THE SKY, THEREFORE ITS SURFACE MUST BE VERY REFLECTIVE:
TRUTH: Look at the full moon in the night sky. It appears bright, in fact, brilliant enough to read the headlines of a newspaper by its light and to see some color. The true tonal gradations of the lunar surface are actually dark gray to nearly black, with an average reflectivity of only 7%. The extremes of reflectivity range from 3% to 30%. The lunar surface appears similar to a macadamized roadway. With about 93% of the sunlight absorbed by the lunar surface, the vivid brightness of the moon is really a contrast difference between its dark surface and an even darker sky. That's why the moon appears so bright at night. At first or last quarter, the moon is about 10% the brightness of a full moon. The moon when it first becomes visible as an exceptionally thin waxing crescent is about 1/1000th as bright as a full moon.

MISCONCEPTION—WHEN THE MOON IS FULL, LUNACY REIGNS:
TRUTH: There is no statistical proof from hospital or police records that people are crazier, or that more crimes are committed, or that more babies are born when the moon is full. However, every nurse or police officer will swear that this simply cannot be so. The misconception probably arises from the condition that the moon appears to be full for a period of four or five days around the actual full moon date. If something weird happens during this interval when the moon looks full, then the blame can be attributed to the full moon. If there really would be a physiological or tidal effect on humans associated with the alignment of sun, Earth, and moon, then there should be similar occurrences happening during the new moon phase when the alignment of these three bodies are similar. In both cases the moon and sun are pulling in tandem causing the greatest tidal strain to occur on the Earth. No such phenomenon is reported for the new moon phase.

METEORS, METEORITES, AND METEOROIDS

MISCONCEPTION—METEORS FALL TO THE EARTH'S SURFACE:
TRUTH: There is a type of celestial fireworks that has been witnessed by humans since the dawn of their existence. They are called meteors, or more commonly, shooting stars. A meteor is the flash of light left by a falling meteorite which hits the ground to end its flight. Whenever you observe a shooting star piercing rapidly through the black night sky, you are most likely witnessing the final chapter in the existence of an extremely small chunk of dross spewed from the nucleus of a comet. The flash of light is created by air molecules which are set aglow (ionized) as the meteoroid slams into our protective atmosphere. Entry velocities range between 7 and 45 miles per second. If the air is unable to stop or consume the meteoroid completely, a piece of it will reach the Earth's surface, now to be known as a meteorite. Meteorites most likely originate from the asteroid belt as iron, rock, or ice-rock fragments formed through the collisions of asteroids and comets. Meteoroids are these same objects, plus cometary dust, which can be found in space orbiting the sun. Meteor, meteoroid, and meteorite are three of the most commonly maligned words in astronomy. Part of the problem stems from a lack of commitment by the professional community to use these words correctly in their own writings and discussions. Astronomers, most of whom are educators, seem to use the words "meteor" and "meteorite" interchangeably. Another inconsistency with the correct usage of these terms surely must stem from Meteor Crater, a nearly

one mile-in-diameter METEORITE crater located just off I-40, 58 miles east of Flagstaff, Arizona near the town of Winslow. It was formed about 49,000 years ago by a small 100 yard-in-diameter nickel-iron asteroid which struck our planet. The impact produced a crater that was over 4000 feet across and 700 feet deep. Had this event occurred in modern times, it is believed that the "kill zone" for all living creatures would have reached a radius of two to three miles from the center of impact. The shock wave would have produced hurricane force winds in Flagstaff. Make no mistake, Meteor Crater is incredibly spectacular, and well worth the visit, but it was made by a meteorite.

MISCONCEPTION—METEORITES ARE HOT WHEN THEY HIT THE GROUND.
TRUTH: In cases where meteorites have been witnessed to fall to the ground and then, in a short time period, were examined or handled, they were cold to the touch or were coated with a layer of frost. During their swift flights, the surfaces of small meteorites are heated to incandescence, several thousand degrees F., and their surfaces ablated (removed) rapidly by Earth's atmosphere. This process is happening to only a very thin layer of the meteorite's surface, and its duration would be short, under 15 seconds. The rest of the body remains at its space temperature, hundreds of degree below zero. In a small meteorite the atmosphere eventually slows the object until it is in a free fall with a terminal velocity of about 200 miles per hour. This could occur dozens of miles above the Earth's surface, giving the meteorite five to ten minutes of free fall before it strikes the ground. The scenario is quite different when a massive meteorite strikes the Earth because it does not lose a substantial part of its space velocity before hitting the ground. Entrance velocities of 10-20 miles per second are the norm. The meteorite's interior is cold upon impact, but 50 percent of its kinetic energy (energy of motion) goes into producing heat. Within a second or so after impact, the area around ground zero, which includes most of the meteorite, is compressed, pulverized, melted, and vaporized constructing a crater that is much larger than the impacting body.

PLANETS

MISCONCEPTION—JUPITER WILL BECOME A STAR ONE DAY:
TRUTH: Based upon current theories of stellar formation, Jupiter would need about 70 times its mass to evolve into a star. Put in another way, about 70 Jupiter-like planets would have to be dumped into Jupiter in order for there to be sufficient material to create the internal temperatures and compression necessary to allow thermonuclear fusion to take place. Jupiter is destined to continue slowly cooling like it has been for the past five billion years since its formation. Incidentally, the least massive of stars, about 70 times the mass of Jupiter, would have a diameter slightly smaller than Jupiter. The Arthur C. Clark film, ***2010,*** didn't quite get it right. In that movie, Jupiter went stellar.

MISCONCEPTION—JUPITER, SATURN, URANUS, AND NEPTUNE ARE GAS GIANTS:
TRUTH: The Jovian, or Jupiter-like planets, which also include Saturn, Uranus, and Neptune, have extensive gaseous atmospheres which eventually become compressed into liquid oceans of primarily hydrogen and helium. As pressures increase, hydrogen is even forced into a metallic state which is the basis for creating the strong magnetic fields which surround all four Jovian worlds. It would be more appropriate to describe these planets as liquid worlds with extensive gaseous atmospheres.

TELESCOPES

MISCONCEPTION—THE TELESCOPE WAS INVENTED BY GALILEO:
TRUTH: Hans Lippershey (1570-1619), a maker of eyeglasses in Middelburg, Netherlands is generally credited with creating and publicizing designs for the first telescope in 1608. Although his patent for the telescope was never granted by the Dutch government, Lippershey was rewarded generously for his construction of several binocular telescopes. Credit goes to Lippershey because he actually had to have a working instrument to accompany the patent application. His invention was contested by Jacob Metius of Alkmaar, a city in the northern part of Holland in 1608, and several decades later by Sacharias Janssen, also a spectacle-maker in Middelburg. Telescopes became available for sale in 1608. It is probably a myth that Lippershey's son or someone employed in his workshop actually made the discovery of the telescope.
Most people believe that Galileo (1564-1642) was the inventor of the telescope. In reality, Galileo was not even the first person to point a telescope towards the heavens, but he did publish his findings in March of 1610 in a book entitle ***Sidereus Nuncius.*** During his first telescopic observations made in 1609-10, Galileo discovered that Jupiter had four satellites, Saturn looked like three planets (Galileo's telescopes could not resolve the rings), Venus went through phases, the sun had spots and rotated, the moon was a rough and cratered place, and the glow of the Milky Way Galaxy was being created by innumerable unseen stars. Galileo also recognized the military significance of the telescope, but he also comprehended its scientific importance as a tool for expanding humankind's understanding of the universe. In this sense, he accelerated the growth of astronomy as a modern science and gave to it its most important research tool.

MISCONCEPTION—TELESCOPES ARE CONSTRUCTED TO PRODUCE MAGNIFICATION:
TRUTH: Telescopes are an extension of the human eye. Taken in this sense, a telescope's most important function is to gather light. An object too faint to be seen by the unaided eye must first be made bright enough to be seen before it can be studied. This has always been the main purpose of constructing any telescope—to gather light, not to magnify an image. Every time the magnification of a particular telescope is doubled, the field of view and image brightness decrease to 1/4 of their original values. It is possible to magnify an image into invisibility, or to produce empty magnification, a condition where the image is enlarged to a point where no further increase in the amount of detail can be revealed. The light-gathering "power" of a telescope must, therefore, reign supreme in any consideration of a telescope's usefulness. Lower and upper limits of magnification for a reflector are between 6-50 power per inch of aperture. For a refractor the upper limit can be extended to about 60 power per inch. The useful limits of magnification of an 8-inch reflector are between 48 and 400 power. Beyond 400 power the magnification becomes empty.

THE SUN

MISCONCEPTION—IT IS DANGEROUS TO LOOK AT THE SUN OR THE MOON DURING ANY ECLIPSE:
TRUTH: The word "eclipse" means to hide. During a solar eclipse, part or all of the sun is hidden by the moon. In a lunar eclipse the moon hides in the shadow of the Earth. ***A solar eclipse is dangerous to view when any portion of the sun's light-emitting surface, called the photosphere, is visible to the eye.*** However, during the totality segment of any total solar eclipse, the moon's

greater apparent size hides the sun's photosphere completely. This allows for visual inspection of the eclipsed sun with the unprotected eye or through telescopes or binoculars with the filters removed. The totality portion of an eclipse ends so rapidly that observers need to exercise extreme caution when even the smallest amount of sunlight again becomes visible. The dangers of viewing the sun when no eclipse is occurring are even greater than when viewing a partially eclipsed sun because the entire disk of the sun is visible. However, more people are apt to want to view the sun during the partial phases of a solar eclipse because interest in observing the eclipsed sun is very high. On the other hand, viewing the moon with telescopes or binoculars during any portion of a lunar eclipse poses no danger whatsoever. Observing the full moon is safe, since its brightness is about 0.0000023 that of the sun's brightness. We do it all the time. Therefore, viewing the full moon as it enters the Earth's shadow and become substantially dimmer is equally safe.

MISCONCEPTION—THE SUN WILL EXPLODE AT THE END OF ITS LIFETIME: The ***TRUTH:*** sun may be considered to be a typical star, five billion years of age, about midway through its life. At present it is converting hydrogen into helium in its core and will continue to do so for the next five billion years. As fusion continues, the accumulation of helium ash in the sun's interior will cause the core to contract slowly and increase in temperature, thus boosting the amount of hydrogen burning occurring in the core. This will cause the sun to become slightly larger, cooler, and more luminous. Near the end of its existence as a hydrogen burning star, nucleosynthesis will cease in the core and shift to a thin shell surrounding the core, where hydrogen fusion will continue to supply the core with ever more helium ash. This additional material will continue to shrink the core making it even hotter, and rapidly expand the sun's diameter as shell hydrogen burning accelerates. The sun will become a red giant star. About this time the sun will probably become variable, due to instabilities generated in its thin hydrogen burning shell. These instabilities will increase in intensity, eventually causing the sun to shed its outer layers to reveal its inert, hot interior composed primarily of degenerate helium gas. At this point the sun will be called a white dwarf star. Its diameter will be reduced to approximately 10,000 miles. Stars that go supernova are considerably more massive than the sun. The threshold is about nine solar masses, meaning that the star which goes supernova must possess about nine times the amount of hydrogen which the sun currently contains.

MISCONCEPTION—SUNSPOTS ARE STORMS ON THE SUN:
TRUTH: In a way, sunspots are storms, but not in the traditional sense of peoples' conceptions of storms. They have nothing to do with any meteorological effects which may be occurring on the sun. Sunspots are very quiet regions on the sun's "surface," which is known as the photosphere. Here the convective mechanism for releasing the sun's heat has been dampened by an intensification of the sun's magnetic field in that region. The area called the sunspot has become cooler, thus making it appear darker against the brighter, hotter photosphere. The intense magnetic field causes the outward flow of plasma in the sunspot's vicinity to slow, thus causing the cooling and darkening of the area. In a very real sense, the high magnetic fields associated with spots could be called magnetic storms. It is in the vicinity of sunspots that other magnetically induced phenomena occur, such as the arcuate filaments of plasma that form in the sun's corona, known as prominences, or extremely energetic flares which can produce intense auroral displays on Earth and disrupt the transmission of electricity by inducing direct current flows in transmission lines.

THE STARS AND CONSTELLATIONS

***MISCONCEPTION*—**POLARIS, THE NORTH STAR, IS THE BRIGHTEST STAR OF THE NIGHTTIME SKY:

TRUTH: Not so and not even close... It actually ranks as the 48th brightest star in the heavens, if the sun is included. Polaris, however, is relatively easy to spot even from an urban location, but its real importance stems from the fact that its position is near the place where the Earth's axis intersects the heavens. As a result of the Earth's rotation, the heavens to appear to wheel around a point in the sky which during the present era is very near to this star, making it an excellent marker to determine the direction north. The brightest star of the nighttime sky is Sirius, the Dog Star. Follow the three stars of Orion's belt downward to this gem of the winter sky, then compare it with Polaris which can be found by following the pointer stars of the Big Dipper to the first relatively bright star that is encountered.

DEMONSTRATION: Lean your head all the way back and focus on the part of the ceiling which is directly over your head. You are now the Earth and your axis is passing up between your eyes. Rotate slowly and notice how the marks on the ceiling seem to circle the point which is directly over your head. In a similar fashion the two locations in the sky where the axis of the Earth points will be the pivots around which the sky circles.

***MISCONCEPTION*—**POLARIS HAS ALWAYS BEEN THE NORTH STAR:

TRUTH: The Earth's axis wobbles like a top, completing one cycle during a period of 25,700 years. This causes a slow change in the direction where the axis points. At present, the axis intersects the sky at a position that is very near to the star Polaris. Five thousand years ago when the Great Pyramid at Giza, and Stonehenge I were being constructed, the Earth's axis pointed close to the star Thuban, in Draco the Dragon. About 12,000 years into the future the Earth's axis will be directed towards the star Vega in the constellation of Lyra the Harp. This was the star that Ellie Arroway (Jody Foster) discovered to be the source of the extraterrestrial message in the movie ***Contact.***

***MISCONCEPTION*—**THE BIG DIPPER IS A CONSTELLATION:

TRUTH: The star pattern known by the name of the "Big Dipper" is most familiar to Americans. It is called the Plow in England, the Wagon in Germany, and the Steel Pan in the Netherlands. During the Civil War, slaves escaping the South through the network of safe havens, known as the Underground Railroad, referred to the Dipper as the Drinking Gourd. Its location is always found in the northern part of the sky, so the Drinking Gourd made an easy marker to follow as slaves made their way north to freedom. The Dipper is really an asterism, a group of stars which form a picture, but which has not been officially recognized by professional astronomers as a constellation. Ursa Major, the Great Bear, is the official name of the star pattern which Americans refer to as the Big Dipper. The Great Bear is difficult to see from urban locations, so the Big Dipper has continued to remain more popular in this country than its official version. Other familiar asterisms are the Little Dipper, the Pleiades and the Hyades found in Taurus the Bull, Orion the Hunter's three belt stars, the Great Square of Pegasus the Flying Horse, the Great Summer Triangle, composed of the brightest stars of the constellations of Lyra, Aquila, and Cygnus, the Northern Cross, which is part of Cygnus the Swan, and the Keystone which comprises the body of Hercules the Strongman.

MISCONCEPTION—CONSTELLATIONS ARE GROUPINGS OF STARS IN THE SKY WHICH FORM PICTURES:
TRUTH: Constellations are very much like states with official borders. Within these boundaries certain stars may be found to form a picture, but all stars within the boundary are considered members of the constellation. There is no official strategy with regards to how the stars of a particular constellation are to be connected to form a picture. Eighty-eight constellation boundaries encompassing the entire sky were sanctioned in 1928 by the International Astronomical Union, a world-wide congress of professional astronomers which deal with such matters. Constellations are useful to modern astronomers because they allow for an approximate location of all objects in the sky.

MISCONCEPTION—ALPHA CENTAURI IS THE CLOSEST STAR TO THE SUN:
TRUTH: The Alpha Centauri system is the closest stellar system to our sun. What we perceive as Alpha, is really a triple star with its three components, α Centauri A (officially Rigil Kentaurus), α Centauri B (officially Toliman), and α Centauri C (officially Proxima Centauri). Alpha Centauri A and B are about 17 seconds of arc in angular distance. About 2.2 degrees away from Alpha lies very faint Proxima Centauri, currently on the sunward side of its orbit. Therefore technically, Proxima is the closest star to our sun. Proxima Centauri has a planet orbiting it in the habitable zone. Alpha Centauri A and B are about 4.37 light years or 25 trillion miles from the sun. Proxima is 0.2 light years closer to the sun (4.19 light years distant) giving it an orbital period around α Centauri A and B of over 1.4 million years.

MISCONCEPTION—STARS ARE BURNING HYDROGEN:
TRUTH: Although it is customary for astronomers to use the words "hydrogen burning" in connection with the energy production inside the cores of stars, nothing could be farther from the truth. Combustion is a chemical process which releases energy. The elements which partake in the reaction are not changed in any way because of the reaction, but they are rearranged into different compounds after the combustion process. The "burning" which takes place inside of stars results in the creation of new elements through a process called nucleosynthesis. In the sun, four hydrogen protons are eventually fused into one helium nucleus. The process is much more complicated, but the concept is a valid one. In the fusion process some mass is converted into energy as helium atoms are created. This is the mechanism which powers most of the stars that we see in the sky. The sun's mass consumption is about five tons of matter per second to produce the energy we observe coming from its surface.

SPACEFLIGHT

MISCONCEPTION—THE FIRST AMERICAN IN SPACE WAS JOHN GLENN:
TRUTH: Alan Shepard rode his Freedom 7 capsule into a suborbital flight to become the first American in space on May 5, 1961. Shepard later walked on the moon during the Apollo 14 mission in late January 1971. He died on July 21, 1998 from cancer. John H. Glenn, Jr. was the third American (fifth human) to venture into space, but the first **American** sent into Earth orbit. Glenn flew on Mercury-6 (February 20, 1962) and more recently on the Space Shuttle ***Discovery***, STS-95 (October 29 to November 7, 1998). Glenn logged over 218 hours in space. Although Shepard was the first American in space and Glenn the first American to orbit the Earth, the US was upstaged by Russian, Yuri A. Gagarin, on both counts. Gagarin, the first human to be

successfully returned from space, rode aboard Vostok I on April 12, 1961. He also was the first human to orbit the Earth during the same mission which lasted 1 hour, 48 minutes. Gagarin died in 1968. Glenn was still alive as of July 2008.

GRAVITY AND RELATIVITY

MISCONCEPTION—ISAAC NEWTON INVENTED GRAVITY:
TRUTH: Isaac Newton (1642-1727), the great English physicist, never invented gravity. Gravity was one of the four fundamental forces created during the birth of the universe 13.7 billion years ago. It is a condition of any object which possesses mass. Newton was the first person to explain accurately how the force of gravity acted upon matter within our universe. Standing on the shoulders of such eminent scientists as Galileo and Kepler, Newton postulated that the force of attraction between two objects was directly proportional to their masses (the quantity of matter which they contained) and inversely proportional to the square of the distances between these bodies. Mythology recounts that Newton's inspiration for his idea was triggered by observing an apple fall from a tree at his home in Woolsthorpe-by-Colsterworth, England. He pondered the question as to whether the same force of gravity that accelerated the apple towards the ground was responsible for holding the moon in its orbit around the Earth. His investigations led Newton to the conclusion that they were the same force, and the unification of the heavens and the Earth was the result.

MISCONCEPTION—SPACE, MASS, AND TIME ARE CONSTANTS:
TRUTH: Space (length, width, and height), mass, and time are actually variables. The only constant in the universe is the speed of light in a vacuum. Traveling at speeds near that of light (186,282.397 miles/second) would cause our perceptions of the universe to alter with respect to space and time. Specifically, a detected object traveling close to the speed of light would appear to be compressed in the direction of motion. Clocks in that object would appear to be keeping time at a slower pace than clocks in the frame of reference of the observer. The mass of the perceived object would also be increased.

MISCONCEPTION—IT IS POSSIBLE TO TRAVEL FASTER THAN THE SPEED OF LIGHT:
TRUTH: Only the limitlessness of the human mind can imagine an object traveling as fast, or faster than the speed of light. For matter bounded by the laws of physics in this universe, an increase in speed results in an increase in the kinetic energy of the body being accelerated. Since mass and energy are the same ($E = mc^2$), some of the energy is converted into increasing the mass of the object. At the speed of light, the mass of an object becomes infinite. If all of the matter in this universe were converted into energy, there still would not be enough force available to accelerate the smallest amount of matter to the speed of light. The mass-energy equivalence of this universe is thought to be conserved or remains the same.

MISCONCEPTION—A LIGHT YEAR IS A MEASUREMENT OF TIME:
TRUTH: A light year is a standard astronomical yardstick for measuring the distances between objects outside of our solar system. One light year represents the distance that light travels during a period of one year. This distance is equivalent to approximately 5.8 trillion miles.

MISCELLANEOUS

MISCONCEPTION—COPERNICUS WAS THE FIRST PERSON TO GIVE US THE CONCEPT OF A SUN-CENTERED UNIVERSE:

TRUTH: Actually, it was the Greek, Heracleides (388 BC-315 BC) and later, Aristarchus of Samos (310 BC-230 BC) who first entertained the heliocentric notion that a rotating Earth could be in revolution around the sun. The concept lost favor to the geocentric model of the universe which was the synthesis of hundreds of years of inductive reasoning practiced by Plato, Eudoxus, Aristotle, Hipparchus, Ptolemy, and others. The Greeks never intended their ideas to represent reality, but by the time of the Renaissance, Ptolemy's geocentric model was thought to portray accurately the true order of the cosmos. Copernicus realized the inexactness of the cumbersome geocentric models to predict accurately planetary positions and borrowed ideas from earlier Greeks to simplify the system into a heliocentric model. Copernicus computed the mathematical details of this system to show how the revolutions of the planets around the sun could account for the observations of planetary motion witnessed in the sky. Ironically, after Copernicus completed publication of his theory in 1543, under the title of ***De Revolutionibus Orbium Coelestium,*** (***On the Revolutions of the Heavenly Spheres***), astronomers could not decide by observation which theory produced the better fit. It appears that the simplicity of the Copernicus's theory began to win converts, particularly in the Protestant countries of Europe. The dilemma of which theory was superior was finally settled by Johannes Kepler in 1609 when he used the Copernican model to solve correctly for the changes which Tycho Brahe had observed in the positional shifts of the planet Mars. When Kepler used ellipses to explain planetary motions, Tycho's data could be made to fit precisely with the orbital characteristics of Mars. In short order, the reinvented heliocentric theory as proposed by Copernicus became one of the cornerstones of Renaissance thought.

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