SESSION THREE: ARCHAEOASTRONOMY

Archaeoastronomy is the practical use of astronomy as it applies to early cultures. It is of interest to astronomers and archaeologists because it encompasses the study of astronomical principles employed in ancient works of architecture (sometimes referred to as astroarchaeology) as well as the practice of astronomy and methods of observations among ancient peoples.

ORIGINS OF ASTRONOMY AND ASTRONOMICAL OBSERVATIONS

The importance of astronomy to all ancient cultures stemmed from a practical need to establish a precise method for telling time, monitoring agricultural events, performing religious ceremonies, and regulating governmental activities. Early people discovered that the systematic progression of the seasons was matched to the rhythmic motions of the heavens, and that the sky was a far more accurate indicator of these cycles than making systematic observations of the weather.

People realized that the movement of the sun across the sky could fix the day and its divisions, while the changing phases of the moon established the month ("moonth" in Old English). By observing the rising or setting of a specific star when near the sun (heliacal rising or setting), the year could be defined. And, because there were seven objects which moved against the starry background; five planets, the moon, and the sun, the popular notion of the week came to fore.

Ancient cultures did not understand the true physical nature of these seven wanderers in the heavens, so it was only natural to deify them and to closely monitor their changing positions. Those individuals who became proficient in these tasks were able to wield enormous power with the populace and ruling infrastructures; so much so, that they were venerated as priests and allowed to exist as a separate, almost untouchable segment of society. They designed temples with astronomical alignments to track the extreme positions of the sun and the moon. In a sense, these structures acted as permanent calendars. Eventually, in the Middle East, a complex series of rules were devised to relate this celestial dance as an indicator of human destiny. The pseudoscience of astrology with its many different types of horoscopes was a direct result of this synthesis.

THE ANCESTRAL PUEBLOANS OF THE CHACOAN PHENOMENON

About 500 AD, Native Americans who lived in the upper Rio Grande, Colorado, and San Juan river basins of what is today, Utah, Colorado, Arizona, and New Mexico, began to abandon their nomadic existence for the richer rewards of a more stable and settled farming lifestyle. Instead of seasonal migrations from region to region, as hunters and gatherers, crops were planted on a regular basis to insure a more consistent and varied food supply. In good years, food surpluses were realized which helped sustain villages against times of famine. Collectively these people were known as the Ancestral Puebloans. The Navajo never knew the Ancestral Puebloans. When they migrated into the Four Corners region during the fifteenth century (1400s), they only discovered their silent ruins.

The Ancestral Puebloans lived in harmony with nature, and as a result they were keen observers of the Earth and the heavens. Most of their waking hours were spent out-of-doors surrounded by an expansive azure sky and canyon walls. They could tell impending weather changes by monitoring insect activity or wind direction. The rhythmic changes of the heavens set the tone for daily, monthly, and yearly calendrical cycles. Farming was difficult because rainfall was scarce, and what rain fell evaporated quickly in the dry desert air. Most of the annual precipitation came in short bursts, during thunderstorms that occurred mainly in the spring and summer months and averaged about 8.8 inches per year. Temperatures could range from well below zero on the coldest winter mornings to over 100 degrees F. on the hottest summer afternoons.

The Ancestral Puebloans dwelled in family or clan units on mesa tops or in the many protective enclaves afforded by surrounding cliff walls. They built their pueblos (towns) and ceremonial structures from the abundant sandstone rock which was all around them. A distinctive feature of pueblo architecture was the kiva, a roofed ceremonial room, found usually below ground level, and almost always reserved for men. This may possibly be explained by the fact that Ancestral Puebloan society was matriarchal. Women held property rights, family names, and clan affiliations were passed down through the female. Divorce, Ancestral Puebloan style, was simply the wife putting the husband's belongings outside of her pueblo. Men and boys had to have a place to congregate, and the kiva was thought to be used to that practical extent, as well as for religious ceremonies.

Ancestral Puebloan men and women were short and lean. Average heights were about five feet, slightly higher for men and slightly lower for women. Weights were about 100 pounds. Life spans averaged under 30 years with men living longer than women. Arthritis and tooth decay were often contributing factors to an early death, as well as a high child mortality rate, especially in times of famine.

EARLY CULTURES AND THE SKY

A. **What were the conditions which allowed ancient people to make good astronomical observations thousands of years ago?** The culture had to possess a
   1. Functioning language or some method of communication
   2. Practical, working knowledge of mathematical principles
   3. Sufficient longevity of its population to observe the repetition of cyclical events

B. **Early people probably did not understand the relationships in movements** between the Earth, moon, and sun. They were, however, able to measure their positions and establish alignments which served as monitoring devices.

C. **Objects and observations of interest to early humans**
   1. **Sun:** Solstitial positions of the sun—June 21/December 21
      a. The sun rises and sets at positions most north or south of east and west respectively.
      b. Noontime positions of the sun are highest and lowest for the year.
      c. Length of the day is longest or shortest for the year.
   2. **Moon:** Major and minor standstill positions. These represent the extreme positions of moonrise and moonset along the horizon. They are created by the five degree inclination of the moon's orbit to the plane of the ecliptic.
   3. **Helical rising of a star:** The Egyptian's first observations of Sirius before the rising sun overpowered it in the dawn sky pinpointed the beginning of their year and the annual flooding of the Nile River.

4. **Bright Stars or star clusters and their rising or transit positions** signaled seasonal changes. The rising, setting, or transit positions of the Pleiades were used by the Aztecs in Mexico to establish calendrical cycles and the construction of cities.
5. **Conjunctions** (objects appear close together in the sky) **and eclipses** of the sun and of the moon.

D. **Methods of observation**

1. Introduction
   1) **Menhir:** Standing stones which were used as positional markers, usually associated with European megalithic sites.
   2) **Foresight:** A distant mountain or conspicuous geographical feature which the sun rises or sets behind.
   3) **Backsight:** The position from which the observations are conducted.
2. **Stationary observer:** The observer watches the changing position of the rising or setting sun against the features of a distant horizon. Stone circles or other isolated menhirs between the backsight and foresight could have been used as markers to indicate the extreme positions of the sun or moon or other religious and agricultural events. In this manner a calendar could have been established. The use of intervening menhirs in Native American observations did not usually occur.
3. **Observer moves:** Distinctive notches on hillsides located miles away from the observer could have been used as foresights. The observer would have positioned himself (at a backsight) so that each day the sun would have risen or set behind the same geographical point, such as a notch in a mountain range. Since the location of the sun would have shifted from one day to the next, the observer would have continuously changed his backsight location to keep the sun rising behind the same geographical location. He could have marked these changing positions with a series of stones. He would have easily noticed when the solstice occurred, *marked by the most northerly or southerly rising positions of the sun*, since afterwards, he would have been retracing his steps as the sun moved in the opposite direction.
4. **Windows/Ports** (small openings) **and doorways, etc.:** A building is designed in such a manner that hallways/doors/windows (ports) permit the passage of sunlight or moonlight into certain parts of the structure at certain key times of the year or when these objects are in certain key positions. The entire structures themselves or the alignment of ports create the markers which can be used to establish a yearly calendar.
5. **Sun Daggers:** The passage of sunlight through natural or worked rock formations creates a dagger-like image on another rock face at certain key times of the year. The most famous of these observatories is the sun dagger atop Fajada Butte in Chaco Culture National Historical Park in northern New Mexico.

NOTES

Date: ________________________________

1. ___________________________________ 3. _________________________________

2. ___________________________________ 4. _________________________________

List team members: A team must have a minimum of two members and cannot exceed four individuals in total. Each team member will receive the same grade.

SAVE YOUR PEOPLE! WIN THAT GIRL!

(10 points)

Tsin Kletsin has just assumed control of the Great House, known as Aztec, fours day's walk along the Great North Road from Pueblo Bonito, and you, Chacra Vida, as one of his trusted aides with a great knowledge of the sky and its motions, has been put in charge of formulating a calendar so that Tsin Kletsin's subjects will know when to plant and harvest crops as well as to celebrate religious festivals. Unfortunately, the five year drought and ensuing warfare between Great House warlords has destroyed all formal records of past astronomical observations, as well as the great sunroom calendar at Pueblo Tsin Kletsin, which your grandfather helped to construct about 40 years ago.

Because you are smart, you have kept a vigilant watch over the heavens in anticipation of this opportunity. You know that if you are successful and please the warlord, Tsin Kletsin, you will gain great wealth and get to marry the woman of your wildest fantasies. Tsin Kletsin's young, sexy daughter has caught your attention, but she has been promised to a much older past rival of Tsin Kletsin to cement a military alliance between the two Great House chiefs. Success in this venture would probably be enough to make Tsin Kletsin think your way.

You also know that if you fail in your attempt to establish a calendar, the Vida family name will be purged, and you will suffer a slow, horrible death by being abandoned by Tsin Kletsin and his followers. How will you use the sky and its various objects to establish a calendar and save the day for Tsin Kletsin, as well as secure the king's daughter for your wife?

Grading: The determination of an astronomical object (sun, moon, stars, constellations, planets etc.) to be used in creating the calendar is the team's choice. Teams should consider making a drawing to clarify the solution. Only use one astronomical object to determine your calendar. Teams will describe the following:

1. **What astronomical object will be used to create the calendar? (1 pt.).**
2. **What will be the astronomical effect(s) that you will be observing? (2 pts.).**
3. **How will the calendar repeat itself in a year's time? (2 pts.).**
4. **How will you conduct the astronomical observations, and what device/ equipment will you use/build to solve the calendar problem successfully? (5 pts.).**

The team's solution will be written on the back of this paper. Only one paper should be submitted per team, but each team member should have a copy of the information.

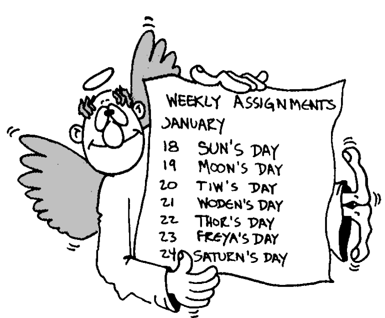
Save Your People! Win That Girl!
Team solution

(1 pt.) What astronomical object will be used to create the calendar?

(2 pts.) What will be the astronomical effect(s) that you will be observing?

(2 pts.) How will the calendar repeat itself in a year's time?

(5 pts.) How will you conduct the astronomical observations, and what device/equipment will you use/build to solve the calendar problem successfully?
A drawing may prove useful here.



Sunday	**Sun**
Monday	**Moon**
Tuesday	**Mars**
Wednesday	**Mercury**
Thursday	**Jupiter**
Friday	**Venus**
Saturday	**Saturn**

Name ______________________________ Date ______________

Name ______________________________ Moravian University

ARCHAEOASTRONOMY BUBBLE PICTOGRAPH

Instructions: In Session Two of your Astronomy Survival Notebook, you will find the Ancestral Puebloans-Archaeoastronomy Wordlist associated with the Four Corners region of the United States. Your assignment is to create a bubble map showing the relationships of the various words to each other. The starting point is the word 'archaeoastronomy' noted below. If you prefer to start with a clean sheet of paper, then use the back of this one. An example of bubbling might be Allentown—Schools—William Allen—Science—Astronomy—Archaeoastronomy. As you bubble outward, you should become more specific. If bubbling does not make any sense to you, please see Mr. Becker for another example.

Archaeoastronomy

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Name ________________________________ Date __________________ Moravian University

TRADITIONS OF THE SUN: CHACO CULTURE

Your assignment is to log on to http://www.traditionsofthesun.org/viewerChaco/ and take a journey back into the time, about 1000 AD, when the Ancestral Puebloans lived in what today is northwestern New Mexico. As you explore Chaco Culture National Historical Park, about which we will be talking in our archaeoastronomy unit, write down a **minimum** of 10 questions that you would like answered about these people who lived in one of the most inhospitable environments in North America. **Submit your questions using word processing, correct spelling, and grammar.** If you wish, you can use this paper as a template and simply print your questions over it, accounting for appropriate spacing, or print the questions on clean paper.

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TRADITIONS OF THE SUN QUESTIONS/ANSWERS:
The Chacoan Phenomenon:
Moravian University Student Questions/Answers by Gary A. Becker

ORGANIZATION OF CHACOAN CULTURE

1. **From where did the Chacoans migrate?** They were basically the indigenous people of the region that had been there for thousands of years prior to what we know as the Chacoan Phenomenon. However, starting between 900 and 1400 AD, Navajos began coming into the region from northern Canada.
2. **How did the culture transition from hunter-gatherers to settled farmers?** Seeds from gathered plants were sown along migration routes to supplement hunted and gathered food when the group returned the following year. This evolved into clans staying in one location while they tended crops and used hunting to supplement their dietary needs.
3. **What was the impetus for the Chacoan Phenomenon?** Rains that fell more consistently, perhaps coupled with a Mesoamerican influence from northern Mexico, may have been the focus for organizing.
4. **Why was Chaco Canyon picked as the culture's centering place?** Chaco Canyon with its surrounding mesas provided an ample means for collecting water when it rained. Fajada Butte may have had a centering influence on the location of Chaco Canyon as a capitol district because it could be seen from great distances. Supposedly, every Great House either had either a direct view of Fajada Butte or a direct view from a shrine that saw Fajada and the Great House from its location.
5. **How did the Chacoan culture adapt to such extreme changes in the weather?** The Ancestral Puebloans had the means and the sophistication to provide appropriate clothing, shelter, and sustenance during the warmest and the coldest periods in the canyon. Pueblo structures made from stone and mud would have provided more comfort during the warmer summer and winter months. Underground kivas with their fire pits would have also been cooler in the summer (no fire) and warmer in the winter, similar to a basement in the summertime. Building constructions, such as Pueblo Bonito's D-shape form opening to the south, may have focused solar infrared radiation into their plazas to warm workers during the winter. Still, life in a high desert environment, where the summer highs can reach over 100 degrees F. (Record high was 106 degrees F., recorded on July 13, 1942) and the record lows can fall well below zero in the winter (-38 degrees F. on the morning of December 12, 1961—record low), would have caused much suffering among the population in the canyon.
6. **How was knowledge transferred from one generation to the next generation?** Information and ceremonies were learned through language, dance, and rock art (a picture is worth a thousand words). Skills were most likely taught through apprenticeships transferred from father to son, mother to daughter.

7. **Why did the Ancestral Puebloans choose NW New Mexico instead of a place that was more sustainable?** Chaco was their world. They were familiar with its challenges, and they could make it work for them. Why move? I have trouble with the interpretation that they stayed there because it was hard. Remember that when conditions became too unbearable after 1137 AD, the Chacoans began leaving the canyon in search of a better place.

8. **Why locate in a canyon?** There is a major arroyo which runs through Chaco Canyon (intermittent water supply). The surrounding mesas could act as a collecting area for more water which streamed off the walls and could be dammed for future use at strategic locations near the canyon walls. The location of Great Houses near canyon walls and with many entranceways also indicates that the Ancestral Puebloans were initially at peace with one another.

9. **When did construction begin in earnest in Chaco Canyon?** About 850 AD…

10. **What was the extent of the Chacoan culture?** The Chacoan Phenomenon took place in the Four Corners region where New Mexico, Arizona, Utah, and Colorado join. The greatest population densities occurred in northwestern New Mexico. Pueblo culture can be found as far west as the Grand Canyon (AZ), south into central Arizona, SE into the Rio Grande River Valley in central New Mexico, and north through SE Utah and SW Colorado.

11. **Did the Chacoans get along with other nearby cultures?** Yes. We know they traded with Mexico to the south and areas in coastal California to the west, as well as regions in Arizona for goods and animals that were important to their culture.

12. **What types of artifacts were discovered from this culture?** Everything that one would expect from a group of people living communally and comfortably have been discovered: clothing, pottery, food, jewelry, hunting equipment, ceremonial artifacts, and of course, the actual bones of the Ancestral Puebloans. The Chacoans did not write, but they did leave pictorial/religious representations of their culture on the rock walls of Chaco Canyon.

13. **How does a dry farming system work?** Dry farming is used in areas where irrigation is not feasible. Planting in sand dune fields which conserve moisture between the grains of sand (Hopi), using rock cairns which collected moisture at night via dew that dripped and transported small amounts of water to the ground, and positioning plants much farther apart helped maximize the usefulness of the little rain that fell. Not all Chacoans practiced dry farming. Some pueblos irrigated their crops, using the flat mesa tops to collect water which was brought into the canyon through natural arroyos, then dammed and diverted through channels and canals. Irrigation was only available to pueblos that were near sources of water. Some groups planted crops in slow moving washes (arroyos), where the possibility existed to receive more water from distant rainfall.

14. **What did the Chacoans eat?** Corn, beans, squash, berries, supplemented by game, such as deer, bear, rabbits, coyotes, etc. …

15. **What would be considered the apex of this civilization?** 1050-1080 AD… The greatest amount of construction was occurring during that time. Life was peaceful and prosperous.

16. **Were droughts the main cause of this culture's decline?** Yes. The first drought occurred in 1097 to 1103 AD, followed 30 years later by a more severe drought from 1130 to1137 AD. Starvation, malnutrition, and warfare were the result.

17. **Were there wars between the Chacoans and other outside groups?** There seems to be no evidence for this during the beginning of their great building period. Near the end of their time in Chaco Canyon, it appears as if Great Houses fought each other over diminishing resources, and warlords practiced cannibalism as a method of keeping their subject farmers in line. This trend of warfare seems to have become common intermittently until about 1300 AD. It appears as if Mesoamerican (Mexican) influences were the result of this activity.

18. **What happened to the Ancestral Puebloans?** They migrated north into Colorado, establishing places like Mesa Verde and Hovenweep (Utah). Droughts in the late 1200's forced them south to more reliable sources of water like the Rio Grande. The Hopi, Zuni (maybe Navajo), Acoma Indians, and 17 other groups which survived the Spanish conquests are the modern descendants of the Ancestral Puebloans. THEY DID NOT VANISH MYSTERIOUSLY as many sources would want their readers to believe.

19. **What roles did men and women play in Puebloan culture?** Puebloan society was matriarchal. Family names and status were passed down through a woman's clan and not the man's clan. Women held property and had the final say in divorce. Society seemed to be less segregated among the sexes than modern Western culture. Still, men held the leadership positions, were the priests, and did the hunting and fighting. Women tended to the children and the domestic chores.

20. **Were the roles of the people in society predestined by family lineage**? Probably, the answer is yes. Since society was matriarchal, men could improve their status by marrying a woman who belonged to a more prestigious clan.

21. **Were the Ancestral Puebloans conquered by the Spanish**? Yes. Every group except for the Hopi tribe of NE Arizona was subjugated by the Spanish. Most of the Puebloan tribes simply died off from disease and the harsh treatment which they had to endure during the Spanish occupation of the Southwest. The Spanish were interested in God, Gold, and Glory, and the spiritual but pagan Puebloan tribes held little worth to them except in their ability to be Christianized and used as a slave labor force.

22. **What were the rituals that the Chacoans performed?** Our best guess is that these ceremonies were some evolution of the dances and ceremonies we see currently performed by modern Puebloan tribes. However, archaeologists need to be careful about their interpretations because the Spanish occupation devastated the tribes, their cultures, and their traditions. Only the Hopi were not conquered by the Spanish, and they're not telling. All of their important dances have been kept secret.

23. **Is Chaco Canyon still considered a sacred place to Puebloan tribes that surround it?** The indigenous tribes in the area consider Chaco a cemetery where their ancient ancestors lived and died. They advocate that the area be abandoned so their ancestors can be at peace.

24. **How did the Puebloan People accomplish so much without a written language?** Knowledge was passed along from one generation to another through apprenticeships, the spoken word, the memorizations of songs and dances, as well as the rock art which can be found throughout the area. Ancestral Puebloan society was based on consistency and continuity and was not "change" driven like the economies of Western Culture are today.

25. **There is overwhelming evidence that the people from Mesa Verde occupied Chaco Canyon. What was their relationship?** They essentially were the same people that left Chaco a century earlier, returning to the canyon after leaving the area around Mesa Verde. Keep in mind that these sites were never totally abandoned, so even when the inhabitants from Mesa Verde came through Chaco Canyon again, they found the canyon marginally inhabited, but probably without any governmental structure.

GENERAL/SPECIFIC QUESTIONS ABOUT CHACOAN SITES

26. **How were the archaeological sites associated with Chaco Canyon originally discovered**? The first documented trip through Chaco Canyon occurred in 1823. Others took place in 1832, 1849, and the 1870s. The first archaeological dig in the Park, the Hyde Expedition, first started work at Pueblo Bonito in 1896. Over five summers they sent 60,000 artifacts back to the American Museum of Natural History in NYC. However, it was Richard Wetherill, a Colorado rancher turned archaeologist, who persuaded the Hyde brothers to invest their monetary resources at Chaco. He participated at the digs in a leadership capacity until they ended in 1901. In 1901 Wetherill claimed a homestead of 161 acres that included Pueblo Bonito, Pueblo del Arroyo, and Chetro Ketl. His robust digs with his son lead to the Antiquities Act of 1906 which protected prehistoric and historic ruins on US Public Lands. Wetherill lived at Pueblo Bonito until his murder by a Native American in 1910 over a dispute involving a horse.

27. **What were the functions of Great Houses?** Great Houses probably served as ceremonial (religious) centers, government buildings (run by warlords), centers of commerce, storage centers for food; a residence for the warlord, family members, and protectors (military); and astronomical centers where shamans maintained the calendar. Farming communities may have aligned themselves to a particular Great House, then communally stored their food surpluses at this Great House. In times of need they would have retrieved food from the Great House, but not necessarily the same food which they had originally brought for storage. Fees for storage and the protection of their food would have been paid through pottery given to the Great House from the faming community.

28. **Why does Pueblo Bonito have over 800 rooms in it when it was not used primarily as a place to live?** I don't subscribe to the empty room theory that Bonito and other Great Houses were built to be impressive simply by themselves. That is impractical in a world where realism was needed for survival. Storage of surplus food, mainly corn, would seem to have been a more rational approach. The kivas and great kivas would have served as clan lodging places and ceremonial (religious) spaces respectively.

29. **<u>What is the symbolization behind the T-shaped doorways in Pueblo Bonito</u>?** The only one that makes any sense to me is that they represent rain falling from a thunderstorm. The upper portion of the "T" represents cumulonimbus (storm) clouds, while the staff of the "T" signifies the rain. They are special because there are very few of them. A walled up T-shaped doorway is found in the Bonito sunroom which marked the winter solstice sunrise.

30. **<u>How long did it take to construct Pueblo Bonito</u>?** Pueblo Bonito was under constant construction/maintenance from 850-1130 AD. Archaeologists know it went through five periods of intensive building which can be traced in the masonry styles of its bricklayers, and through tree ring studies of the wood used in floor supports and the lintel timbers of doorway which can be used to date the year in which the tree was cut. The bricks used in the buildings were the sandstone rocks of the canyon.

31. **<u>How did the Chacoans transport the logs used in the structures over distances as great as 70 miles</u>?** Once a tree was dropped, it was transported nonstop into the Canyon by groups of runners. If the tree touched the ground, it was considered unusable.

32. **<u>Can we trust dendrochronology (study of tree rings) to be an accurate measurement of age, considering how much the buildings have deteriorated over time</u>?** The answer here is an emphatic yes. Buildings that collapsed or were buried in the sand actually were better preserved than those structures that remained in the open. Dendrochronology allows for the determination of the precise date in which a tree was felled. Trees would have been transported back into the canyon to dry (cure) for a year, then almost immediately used in the construction of lintels for windows and doorways, allowing for accurate dating of these rooms by modern science.

33. **<u>Where is the nearest Great House to Pueblo Bonito</u>?** Pueblo del Arroyo is the closest Great House to Pueblo Bonito. It is less than 150 yards away.

34. **<u>How could they build so high without machines</u>?** The walls and rooms were built simultaneously as the structure rose. The individual stone bricks and mortar would have been easily transported by hand to the construction location. Undoubtedly, scaffolds were used along the high back walls during construction.

35. **<u>How were windows created in the buildings</u>**? Windows were capped with wooden beam lintels and larger flat stones to help to distribute the weight of the overlying walls to the sides. Some windows/doorways were created after the rooms were completed.

36. **<u>Why are there so many Great Houses</u>?** The 160+ Great Houses in the Chacoan world are a testament to the success that this culture had in raising enough food to support a population of several hundred thousand people. At its apex, the population of the Chacoan world was greater than the population of this region today.

37. **<u>What was the purpose of the floor vaults in Casa Rinconada</u>?** They probably were not used for fires as shown in “The Mystery of Chaco Canyon” video. They may have been employed as foot drums for communication, when covered with timbers, or for the ceremonial planting of seeds for the new growing season. The foot drum theory has been tested. The low frequency sounds created by numerous participants simultaneously working the foot drums carries the sound for miles.

38. **<u>Why was Rinconada burned when abandoned</u>?** Puebloan people have a tradition of returning abandoned, broken, or unused structures to the earth. In fact, the entire concept of the kivas may have arisen from the Ancestral Puebloan belief that they originally came from a previous world located beneath the earth.

39. **<u>What is the relationship of Fajada Butte to the Great Houses</u>?** Virtually, all of the Great Houses had a direct line of sight into Chaco Canyon and Fajada Butte. Those that did not, established a shrine from which the Great House and Fajada Butte could be seen from the shrine location. As an extreme example, Chimney Rock, located in southern Colorado between Durango and Pagosa Springs, had a line of sight into Chaco Canyon, 120 miles distant, via Huerfano Mesa, located about 25 miles from Fajada Butte.

40. **<u>How have the buildings stood the test of time</u>?** Roofs rotted and collapsed over the centuries; walls lost their mortar and collapsed. Some buildings were dismantled by the Navajo. Wooden beams were used in the construction of homes by the first archeologists/entrepreneurs who came into the canyon. Some or parts of the Great Houses were buried by wind-blown sand, while some survived nearly intact. The National Park Service has begun to rebury some of the Great Houses because they cannot fund the maintenance costs necessary to sustain them.

41. **<u>Are there Chacoan sites that have yet to be excavated</u>?** The vast majority of the Great House sites have not seen stabilization, preservation, or excavation by archaeologists.

42. **<u>What was the climate like during the Chacoan Phenomenon</u>?** Essentially, it was the same as today’s climate in northwestern New Mexico. It was dry, hot, and cold, with extremes in temperature. Dendrochronology (the study of tree rings) shows that Chaco Canyon had nearly the same amount of rainfall as today.

43. **<u>Over how many years did the Chacoan culture continue construction</u>?** Almost 300 years, 850 AD-1137 AD…

44. **<u>How many structures did the Chacoan culture build</u>?** Literally, hundred of thousands of structures were constructed if one considers the individual pueblos of the farmers.

45. **<u>In Pueblo Bonito and other Great Houses, why were there so many small completely enclosed rooms instead of just one big common area</u>?** The Great Houses were massive structures which needed internal support. If many of the rooms were used for food storage, walled up small rooms might have made them more impervious from animal predators and the decay of the food in storage. The common gathering places for the Ancestral Puebloans were the plazas and the kivas constructed within the Great Houses.

46. **<u>What are the "outliers"?</u>** Outliers are Great Houses which lie outside of Chaco Canyon. They seemed to be positioned about a day’s walk from each other, making seasonal migrations into Chaco Canyon more doable.

47. **How many people visit Chaco Culture National Historical Park each year?** Chaco Culture National Historical Park sees about 30-40,000 visitors each year. There isn't any lodging, restaurant, or gas station at Chaco, making it difficult for long stays unless the traveler is willing to camp.

ASTRONOMY OF THE CHACOAN WORLD

48. **When did astronomers and archaeologists begin to interpret Chacoan structures as having an astronomical intent?** This began in the 1970s, starting with the sun dagger on Fajada Butte. Archaeoastronomy really had its birth with Stonehenge in the 1960s. Stonehenge is located about 90 miles ESE of London.

49. **What did the Chacoans believe the moon, sun, and stars to be**? They must have considered them to be gods that needed to be monitored. This is characteristic of most ancient cultures. Even most modern cultures believe that astrology plays some significance in the lives of its people (95 percent in the US).

50. **Why did the Ancestral Puebloans have such an interest in astronomy?** Cultures deified things that they did not understand. When astronomical objects, such as the sun and the moon were thought to be sacred, a priesthood was established to maintain vigilance over their motions in the sky. Gods don't have to obey rules. They could become scornful and punish The People if they were not being pure of heart and allow the sun to get lower and lower in the sky until it disappeared. These gods could also be beneficial and allow the sun to return to its summer house where planting and a harvest would be anticipated.

51. **How did astronomy affect the everyday lives of the Chacoans?** The Native Americans of Chaco lived mainly out-of-doors, particularly from late spring through mid-fall. The average Chacoan would have known where the moon was in the sky, would have had an idea what the sun was doing (going lower, moving higher) and probably would have known whether the day was lengthening or shortening. Only the priests would have had the knowledge to interpret these motions or how to create a calendar or how to follow it.

52. **Why did the Chacoans build their towns and astronomical observation sites somewhere more hospitable?** Without the ability to see beyond the horizon, making any major move entailed great risk to family members and the clan, in general. In the end, the 1130 drought forced the Ancestral Puebloans to move north into Colorado's Deloris River Valley where Mesa Verde can be found. Other outposts were established in southeastern Utah such as Hovenweep.

53. **How long did it take shamans to formulate accurate calendars to mark the seasons**? No one knows for sure, but there had to be a lot of trial and error involved. Some shaman watching the sun had to make the first prediction. He probably had an apprentice who also made observations along with him. Mistakes were undoubtedly made, and apprentices took over the work of their former astronomer priests, picked a new apprentice, and so on until an accurate sun calendar was established.

54. **How did Puebloans come to understand the motions of the sun so well?** Systematic observations using horizonal markers and building designs seemed to be key factors in forging this understanding of heaven and Earth. Daily observations were made over centuries of time. This information was transmitted orally to apprentices in training who would eventually become the new sun watchers when the old sun watchers died or became too old to perform their duties. Keep in mind that these people lived outdoors for the most part, in wide open areas dominated by a sky where the sun and moon were vividly displayed.

55. **Did the Chacoans map have any calendar based upon the moon?** The 18.61 year oscillation of the moon between its major and minor standstill positions may be recorded in the 19 spirals of the sun dagger calendar on top of Fajada Butte. It has also been speculated that these extreme positions of the moon were recorded in building alignments, as well as in alignments between Great Houses spaced miles apart.

56. **How accurate were their observations?** Astronomical observations were as accurate as those necessary to create a modern day calendar. It was only through such accuracy that the Chacoans were able to cultivate corn with a 95-day growing cycle, separated by 105 days between killing frosts.

57. **How do archaeoastronomers interpret a site as being astronomical?** Initially, this can be done through compass bearings, computer simulations, geodetic surveys, and finally, going to the site to make the confirming observations.

58. **Who observed the stars, the moon, and the sun in Chacoan culture?** It is presumed that astronomer priests who were aligned to specific warlords of the Great Houses made the observations necessary to establish the calendar.

59. **Did the sun watchers mark down any other events other than the winter and summer solstices and the spring and fall equinoxes?** Different crops needed to be planted at different times. Planning for religious ceremonies would also have been important, so it seems likely that the calendar would have been much more complex with regard to the farming cycles of different crops and the regulation of the daily lives of the Chacoans.

60. **Were the cliffs used as landmarks?** The notches and crags at the top of the canyon walls served as excellent markers to create calendars. There are numerous sun stations in the canyon including a very famous altar in the SE corner of Pueblo Bonito.

61. **Wouldn't the canyon tops have made a better location for viewing the sun?** Yes and no… Getting there would have been a chore, especially in the winter. It is thought that sun watchers rose several hours before dawn to begin performing their ceremonial duties. A sun watching station does not necessitate seeing the moment of sunrise. The sun clearing the craggy canyon walls, several hours after it rose, would have been good enough to establish accurate markers for the creation of a calendar.

62. **How did the Chacoans locate the cardinal directions and use the moon, sun, and stars to map out time changes?** Careful and systematic observations over long periods of time were made.
    a. **Sun**: High sun gives the north/south line. A perpendicular to the marker gives east/west. The sun goes through a change in altitude, a change in the rising and setting directions, and a change in the length of the day/night cycle over the course of a year.
    b. **Stars**: Repetition of star patterns during evening twilight or morning dawn on or near the horizon could have determined an accurate year.
    c. **Moon**: Major and minor standstill positions of the moon seem important because of the interpretation of building alignments by archaeoastronomers, but we don't know for what purpose. Certainly, the moon's phase changes occurring over the duration of a modern month would have been noticed and used to establish a shorter sequence of time marked against the solar year.

63. **How did the Chacoans use their knowledge of the sky other than in their building construction?** The answer to this question is unknown because the Ancestral Puebloans did not write. We can only infer the importance that astronomy must have played in their lives by the nonliterary architecture that has been left behind, such as sun watching stations, sun daggers, and calendar rooms.

64. **How did the Chacoans make their measurements of the movement of astronomical objects?** Horizonal observation stations, trees acting as sundials, building alignments, calendar rooms, and natural structures, like the sun dagger slabs, were adapted for calendrical purposes.

65. **Does Pueblo Bonito have a calendar room?** Yes, in the newest section near the southeastern corner is a room that potentially kept the calendar cycle from late October through mid-February. At the winter solstice the rising sun passing through a doorway positioned the light from the sun into a corner niche near the floor of the room.

66. **What role was played by the large Ponderosa pine tree in Bonito's plaza?** The best explanation is a sundial. It was cared for in a special way, and it appeared to be the only tree left living in the canyon during the Chacoan Phenomenon. Pueblo Bonito was built around this tree which lived for about 700 years.

67. **Were the window/door alignments intentional?** It does not appear as if all or most of the windows in the Great Houses were aligned to astronomical events. Where there seems to be an astronomical intent in a window or door placement, a T-shaped doorway or additional construction more recent than the room is in evidence. The new construction, such as found in the Pueblo Bonito sunroom, sculpted the space for an astronomical purpose.

68. **Are there other explanations for the corner windows in Bonito other than the sunroom theory?** No. Only one corner window is linked to a sunroom. The back walls of the other corner windowed rooms in Bonito (six in total) have all fallen.

69. **What was the purpose of the solstice marker near Wijiji?** There are two solstice markers near Wijiji. Both are Navajo and more recent in construction. They functioned in a similar manner to the Ancestral Puebloan markers by denoting the position of the winter solstice sunrise. In both cases the observer sat and viewed the rising sun. In one case the sun appeared above a distant pinnacle (very spectacular and precise), while in the other situation the sun rose from a distant cut in the mesa created by an arroyo.

70. **Was the solstice marker in Casa Rinconada placed deliberately?** Yes. I personally believe that there is validity to the location of the window and niche which holds the sun shortly after sunrise at summer solstice. The reconstruction of Rinconada by archaeologists possibly made the alignment less accurate than when it was originally fabricated. There is still much room for debate about this issue.

71. **How could the Chacoans safely get to the top of Chimney Rock for their lunar observations?** Chimney Rock seems to have been an astronomical center for the greater Chacoan Phenomenon during its later years. The two pinnacles that comprise the markers called Chimney Rock in southern Colorado, Chaco Canyon's must distant outlier, were used for sighting moonrise when the moon was at its major northern standstill position. The pinnacles were used as alignment markers to view the phenomenon and not towers from which the observations were made. Other geographical points in the complex, often marked with a spiral, were used to monitor the sun at its extreme positions.

72. **How did the Ancestral Puebloans manage to line up their walls perfectly with the solstices?** The Chacoans made accurate observations of extreme and midpoint positions of the sun and the moon, so they knew when to make the necessary observations for building alignments. Other calendars, such as the mini sun dagger north of Gallo Campground, may have been used as predictive makers for the preparation of ceremonies and dances.

73. **Why are there only four Great Houses aligned to the sun?** The answer to this question is unknown. Since the sun was so important to the Chacoans, one would think that solar alignments should have been reflected in more building construction sites.

74. **What technique would have allowed buildings to be accurately aligned to one another?** Buildings that could have been seen could have been aligned via line of sight or through the use of the Pole Star, but others, especially buildings which seem to show lunar alignments, would have necessitated surveying techniques. This is still an unanswered question.

75. **Were there conflicts between religion and science?** No. The scientific method was unknown to these people. It was all about religion and being aware of what their gods were doing and making sure that "The People" were in harmony with their gods.

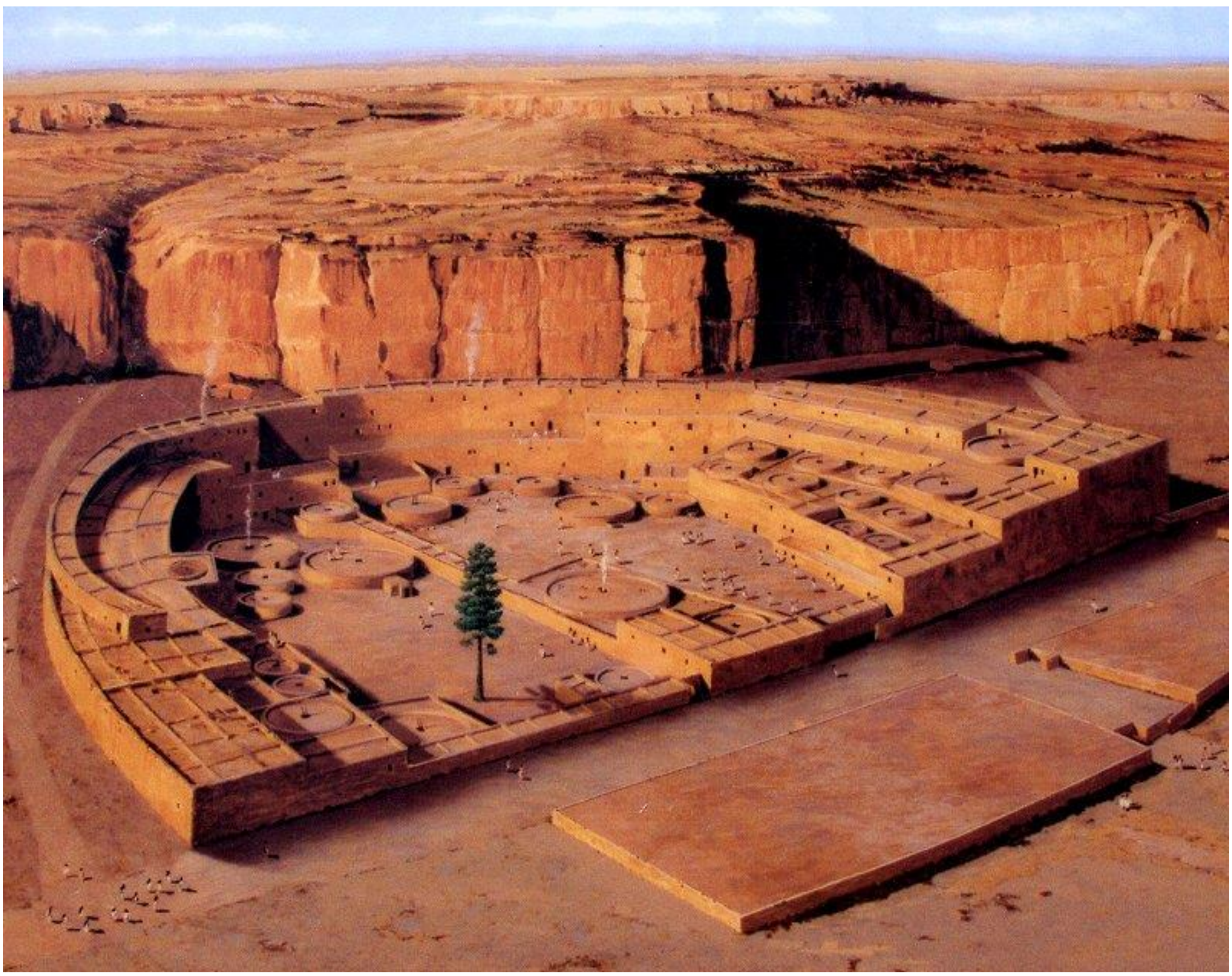
76. **What explanation did people have for Halley's Comet in 1066?** They probably interpreted the apparition of Halley's Comet in a negative way because it was a change occurring against the rhythmic cycles of an ageless sky. Ancient cultures and modern societies have also considered comets in a negative way.

MYSTERIOUS PUEBLO BONITO

(5 points)

Archaeoastronomy is the field of research which tries to understand how ancient cultures interpreted the sky and used astronomy for practical purposes. Below is a reconstruction of Pueblo Bonito, located in Chaco Culture National Historical Park near Nageezi, New Mexico. Its 800 rooms were built in five stages between 850 AD and 1130 AD. Pueblo Bonito was the largest Great House and the center place of the Chacoan Phenomenon. The following features of Pueblo Bonito might be related to astronomy in what way? (1) its D-shaped structure, (2) the wall that is perpendicular to the front wall—**hint: It's due north/south** (3) Bonito's front wall, (4) the round kivas which dot Pueblo Bonito's structure, and (5) the large Ponderosa pine tree which can be seen in the main plaza. Create a jot list on the back of this paper, but be complete in your thoughts.

Archaeoastronomers: Consider this also an exercise in getting into the minds of archaeoastronomers, those individuals who have to interpret and extrapolate astronomical relationships from what they have seen, measured, and learned about an ancient site. Sometime their ideas can be unorthodox (pretty wild), so let your mind stretch when considering the possibilities of astronomical connections with respect to Pueblo Bonito as seen below.



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Name ________________________________ Name ________________________________

1. D-shaped structure of Pueblo Bonito:

2. The wall perpendicular to the front wall:

3. Bonito’s front wall:

4. The round kivas which dot Bonito’s plaza:

5. The large Ponderosa pine tree in the plaza:

6. Other interesting aspects of Pueblo Bonito which may be related to astronomy:

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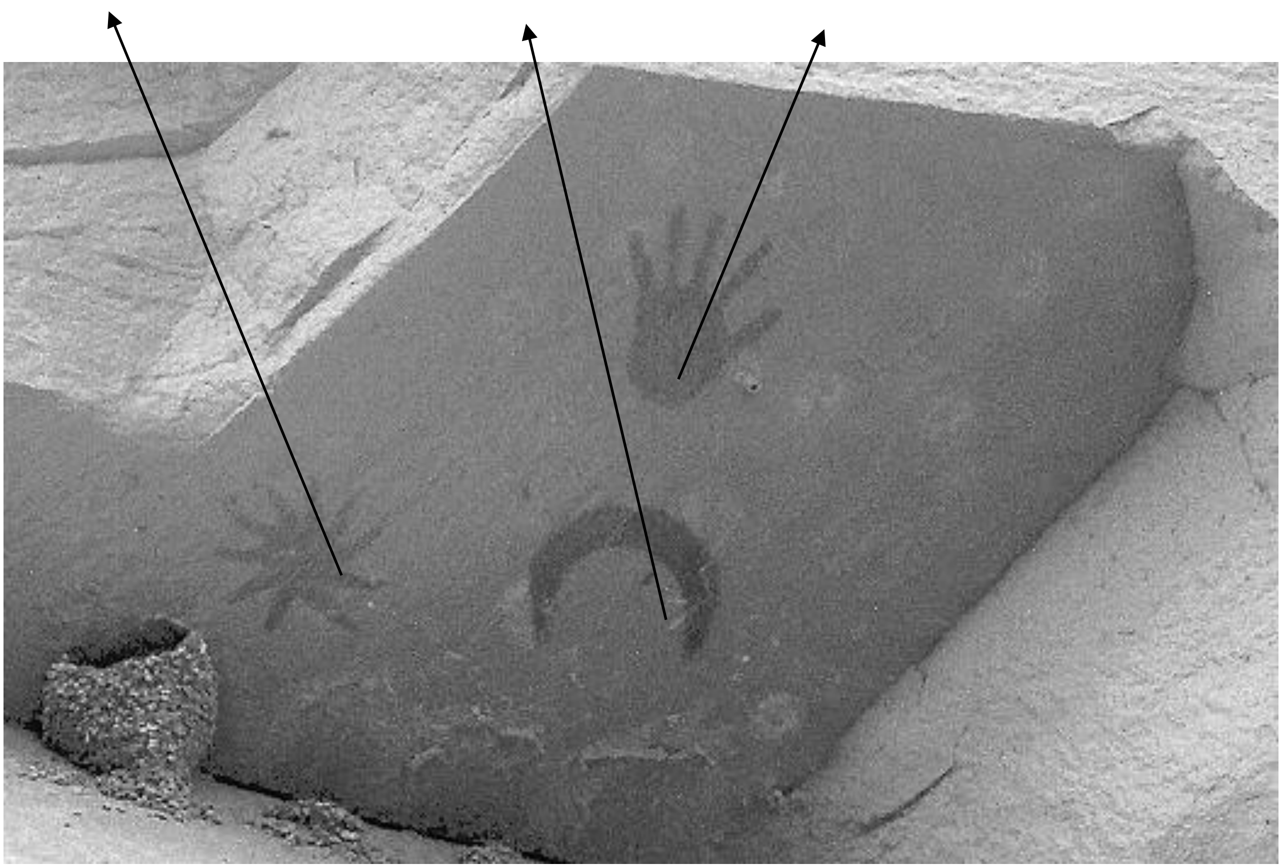
Name ______________________________ Name ______________________________

A PICTURE IS WORTH A THOUSAND WORDS

People have often said that a picture is worth a thousand words. The Ancestral Puebloans had a functioning language, but they did not write. Instead, some archaeologists have suggested that they used rock art in the form of petroglyphs (rock pecking) and pictographs (painted pictures on rocks) to convey ideas that translated themselves into stories. These narratives became the basis for their culture. You have already seen that sun-watching stations were represented by spirals and concentric circles. The photograph that is found below details the three parts of the most famous astronomical pictograph of the Ancestral Puebloan world. It is located in Chaco Canyon near Nageezi, New Mexico. Your task as investigators is to derive a working hypothesis of what this image is trying to convey. Clues to the answer may be found on the next page.

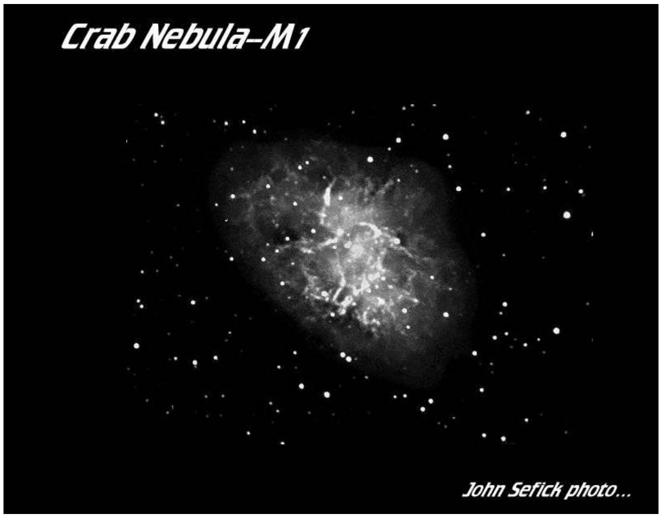
1. 2. 3.

Put it all together. What do you think this pictograph represents?



A Picture is Worth a Thousand Words, cont.

Clue 1



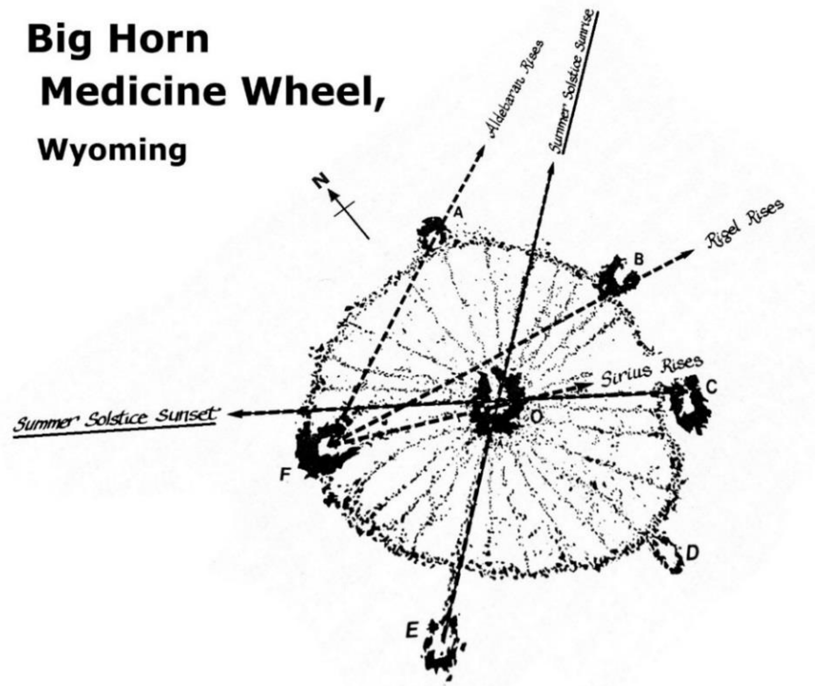
Clue 2

Clue 3

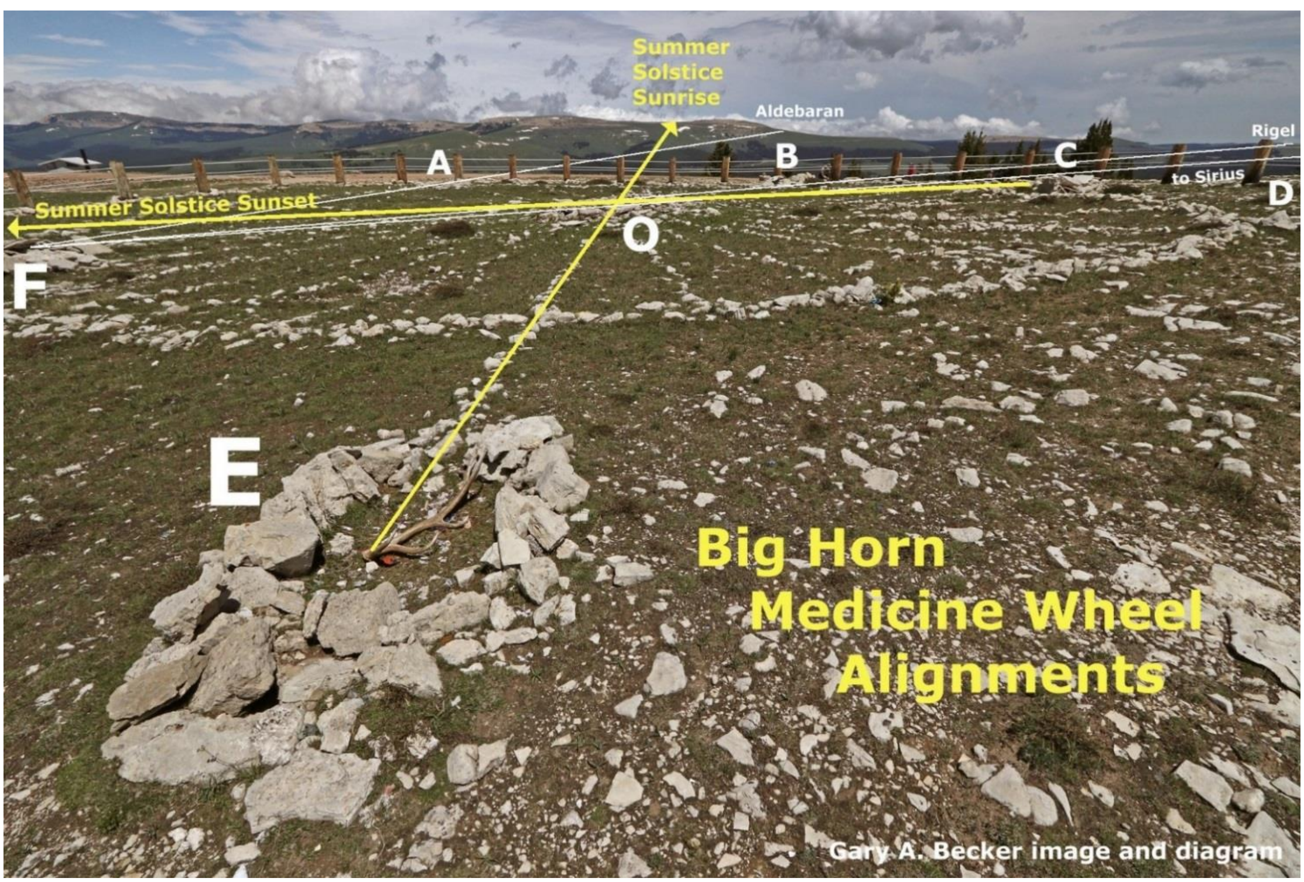
BIG HORN MEDICINE WHEEL

Another American archaeological treasure which needs consideration for its astronomical intent is the great Medicine Wheel located in the Big Horn mountains of north central Wyoming between the towns of Lovell and Sheridan. When I first saw it in 1979, the 80-foot limestone rock circle, with its central raised hub, radiating 28 spokes and six cairns along its circumference, was encased by an ugly metal fence capped with barbed wire. That has all changed. When I revisited the site in July of 2019, the old fencing was gone, replaced by a low, four-foot high circle of vertical posts with three rungs of white nylon rope running between them. Standing behind this aesthetic boundary, the entire wheel was accessible to the eye unobstructed, blending naturally with the open windswept mountaintop and the brilliant blue turquoise sky which dominated the area overhead. The “why” behind the Big Horn Medicine Wheel’s construction is uncertain—legends abound. The Crow tribe believes that the Medicine Wheel was built “before the light came.” Other Crow stories say the sun god dropped it from the sky, and still others say it was built by the “Sheepeaters,” a Shoshonean band whose name is derived from their expertise at hunting mountain sheep (2019 US Forest Service Brochure). A local ranger at the site noted that it may have been a summer sanctuary for the Crow to escape the warmer valley temperatures, as well as marauding bands of more hostile indigenous groups that preyed on the Crow. This would give the Medicine Wheel a more practical use as a calendric device as the solar physicist John A. Eddy proposed in 1974. Using two of the five cairns and the central hub, the wheel points accurately to the summer solstice sunrise and sunset positions, the longest day of the year and the point in the solar cycle where the “sun stills” (solstice) its upward motion before beginning its slow retreat into its cold, winter “house.” Observing from the central hub, summer solstice sunset is opposite to winter solstice sunrise, and summer solstice sunrise is 180 degrees away from winter solstice sunset. In theory on a flat surface, all would be perfect, but to my knowledge the winter solstice alignments have never been tested because by December the Medicine Wheel, positioned at an altitude of 9,642 feet, is covered in deep snow. It was probably only used during the warmer months. In fact when I was there on July 3, 2019, the site was recovering from a major snowstorm just several weeks earlier that had dropped something like five feet of wind-tossed powder on the higher Big Horn elevations. Another cairn alignment also supported the heliacal rising of Aldebaran in Taurus the Bull. A heliacal rising of an object means that it was first seen just before the brightening light of a new day washed it from visibility. This was followed 28 days later by summer solstice and 28 days later by another alignment pair of cairns which pointed to the heliacal rising of Rigel in Orion the Hunter, followed by another pair of cairns about 28 days later which reinforced the heliacal rising of Sirius, the brightest star of the nighttime sky. See the next page for these alignments. Aldebaran may have been utilized as a predictive marker, the ribs of the wheel acting as a counting device to foresee the summer solstice, while the rising of Sirius, 56 days (28 x 2) after the high sun in mid-August, may have been the time to leave the Medicine Wheel because of the encroaching chill of autumn and winter. It is also curious to note that 28 divided into a tropical year of 365.24 days yields 13.04, an interesting number (13) to act as a counting device to mark a year’s passage, had the Big Horn Medicine Wheel been usable year-round. Since the rising and setting of the stars change as a result of the 26,000-year wobble of the Earth’s axis known as precession, it is possible to date when these stellar alignments worked, and therefore, when the Medicine Wheel was in use—1400 AD to 1700 AD. This agrees with the archeological record detailing the time of the construction of the site (Eddy). As always, the great conundrum of archaeoastronomy is that as compelling as these facts may sound, we can’t interview the person or individuals who masterminded and constructed sites like the Big Horn Medicine Wheel to glean their specific intentions, but it does appears that the sky played a significant role in the spiritual lives of these Native Americans. In archaeoastronomy, the stones always pose tantalizing mysteries with multiple interpretations.

Compare the John A. Eddy drawing of the Big Horn Medicine Wheel and its various alignments to the photograph of the same structure, imaged from position E, the cairn that marks the summer solstice sunrise alignment, along with the central hub, against the real landscape surrounding the monument. This is the best example of a Medicine Wheel in North America but not the only one which exemplifies astronomical horizonal alignments.



John A. Eddy, "Archaeoastronomy of North America: Cliffs, Mound, and Medicine Wheels," 1974
In Search of Ancient Astronomies, edited by E. C. Krupp, 1978.



STONEHENGE

Stonehenge: Europe's best known and most visited megalithic observatory

1. Introductory remarks
    a. **Megalithic astronomy:** Deals with structures built from large stones which have an astronomical relationship. **Megalith** means large stone.
    b. **What was Stonehenge?** A megalithic calendar used to monitor the positional movements of the sun and moon for agricultural purposes and possibly for use as a computational device for the prediction of lunar eclipses.
    c. **Location:** In south central England, about two hours west of London, near the town of Salisbury, just off Route A344.
    d. **Size:** Smaller than expected, especially when viewed from the perimeter fence, but impressive when walking within the stone circle and horseshoe.
    e. **Description:** A very shallow round ditch, flanked internally by a low bank (320 feet in diameter) is concentric with a circular group of standing stones, called sarsens (100 feet in diameter), capped with lintels. Inside of the sarsen circle there are five huge freestanding trilithons (three are still complete) shaped like a horseshoe with the open end pointed to the northeast, toward a large menhir called the heel stone, about 70 feet from the ditch and 256 feet from the center of the monument. See the map of Stonehenge on the next page.
    f. **Stonehenge nomenclature**
        1) **<u>Sarsen</u>:** Name given to the large uprights (25-50 tons) which form the circle and central horseshoe. It is also the name of the rock itself. These were found at Marlborough Downs, 20 miles to the north of the monument.
        2) **<u>Lintel</u>:** Term used to denote the cross slabs of worked stone which lie on top of the sarsens.
        3) **<u>Bluestones</u>:** Smaller stones (five tons apiece) which were transported mostly by water from the Prescelly Mountains of southern Wales to Salisbury Plain. Their significance is unknown.
        4) **<u>Trilithons</u>:** Name given to the freestanding sarsen and lintel caps, five in total which form the central horseshoe. These were used as key seasonal markers.
        5) **<u>Heel stone</u>:** A large menhir about 256 feet to the northeast from the center of the Stonehenge structure. The sun rises over the heel stone on the summer solstice.
        6) **<u>Aubrey holes</u>:** A series of 56 holes spaced at 16 foot intervals forming a circle 288 feet in diameter. They may have been used as a predictor for lunar eclipses.
        7) **<u>"Y" and "Z" holes</u>:** There are 30 Y holes and 29 (possibly 30) Z holes. The Y's form a circle about 35 feet outside of the sarsen circle, and the Z's form a smaller circle lying from five to 15 feet outside of the sarsen circle. They may have been used to measure the phase period of the moon, which is 29-1/2 days. Even though there is a number 30 Z hole, Z hole 8 is missing, allowing for only 29 Z's. Sometimes the Aubrey holes are referred to as the X holes.

8) **<u>Station stones</u>:** Originally there were four sarsen stones in the shape of a rectangle (two are missing) which paralleled the axis of the summer solstice sunrise.

9) **<u>Menhir</u>:** A large standing stone that may have been used as a positional marker

2. **The construction of Stonehenge:** Three major phases

a. **Stonehenge I:** A ditch-bank circle 360 feet in diameter was excavated. It had an opening to the northeast and the south. The soil from the ditch was interior to the ditch which is unique for megalithic ditch-bank structures. The 56 Aubrey holes were also excavated during this earliest period.

1) **Date:** 3100 BC

2) **Construction period:** unknown

3) **People:** Late Stone Age people (Windmill People) who came from Europe (4300 BC) bringing with them agriculture, cattle, primitive wheat, flint, bone tools and pottery. They built long earthen barrows for the burial of their dead and began burying people near Stonehenge for the next 500 years.

b. **Stonehenge II:** This phase of construction is no longer evident on the surface of the ground. It appears from posthole discoveries that some type of wooden structure was build interior to the Aubrey holes and that cremated human remains including pottery was put into the Aubrey holes. Stonehenge's function at this time seems to have been a closed cremation cemetery.

1) **Date:** 3000 BC

2) **Construction period:** unknown

3) **People:** Beaker people. Came from Holland and the Rhineland (Germany). They introduced the use of worked metal and beer to Britain and dominated the economy of southern England. They got their name from the elaborate clay beakers they often buried with their dead.

c. **Stonehenge III:** Timber is abandoned for stone during this period.

1) **Date:** 2600 BC

2) **Construction period:** 50 years

3) **People:** Wessex people. The blending of various clans of Beaker people formed the Wessex group. Dominated by a wealthy, powerful aristocracy whose trade routes extended into central Europe, Ireland, Crete and Greece (Bronze Age).

4) Three different periods of construction

a) **3-I:** 2600 BC: The Q and R holes were dug interior to the Aubrey holes. They may have held blue stones which were transported by water from the Prescelly Mountains in southern Wales (160 miles distant) or from erratic boulders which were deposited from glaciers much nearer to the site. Their use is unknown. A ditch and bank avenue was constructed (but not completed) to the northeast to precisely match the summer solstice sunrise and winter solstice sunset. The slaughter stone and heel stone may have been brought in and erected during this period. The station stones may have been placed during this time

b) **3-II** 2600-2400 BC: The 30 sarsens and their lintels for the outer ring were brought to the site from Marlborough Downs about 21 miles north of the site. They were fashioned into a circle, 110 feet in diameter, 30 of them with lintel caps. Each of the standing sarsens was about 13 feet high and seven feet wide. The sarsens were tapered and dressed with tenons (protrusions) while the lintels had mortise holes. The lintels which had a slight curve in them were tongue and grooved for a more precise fit. They widened with height to present an architectural impression that the sides were parallel. Five free standing trilithons with each with a lintel cap were constructed in a horseshoe shape interior to the sarsen circle. The most massive of the trilithon sarsens weighed 50 tons. Four station stones were erected and the causeway was lengthened to the Avon River two miles to the northeast.

c) **3-III** (later than 2400 BC): The blue stones were re-erected in a circle interior to the sarsen horseshoe.

d.) **3-IV** (2280-1930 BC): The blue stones were rearranged and a horseshoe of bluestones were erected interior to the large sarsen horseshoe.

e) **3-V** (2280-1930 BC): The northeastern section of blue stones were removed, creating a horseshoe like appearance for both sets of blue stones.

f) **1600 BC:** The “z” and “y” holes were dug exterior to the sarsen ring. There are 30 in each circle or 29 and 30. The z-holes are interior to the y-holes.

NOTES

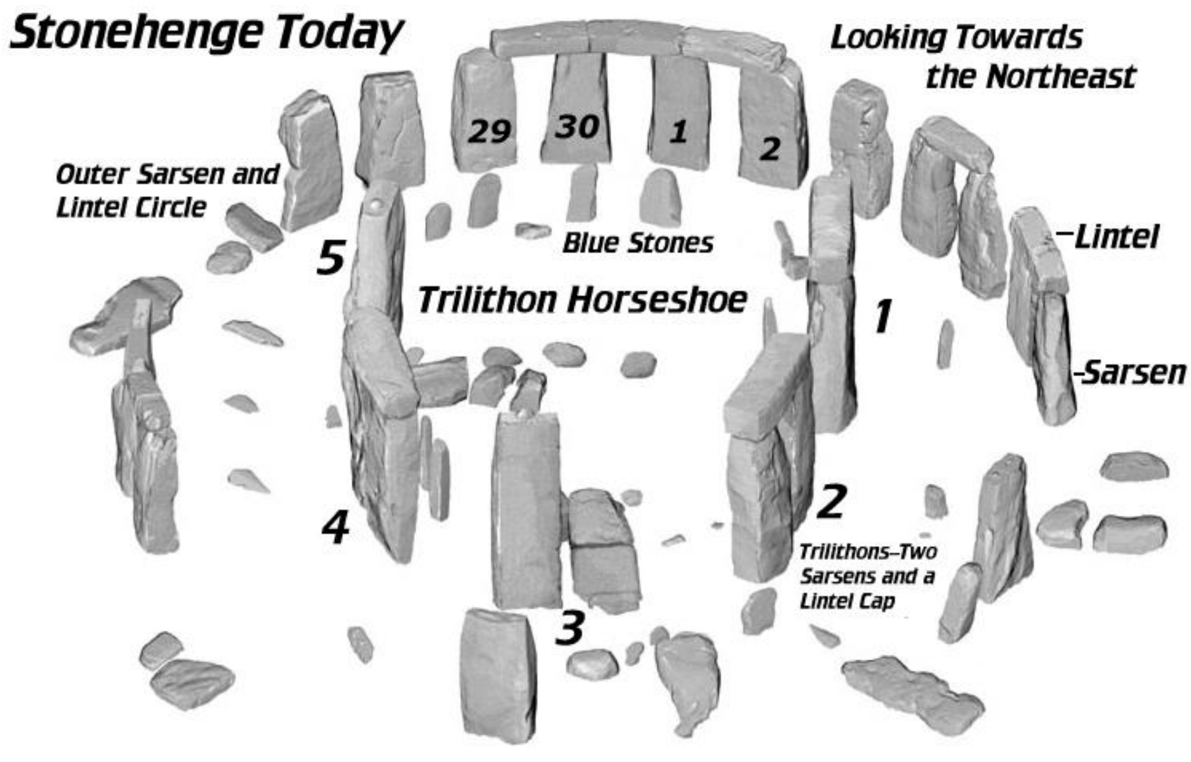
STONEHENGE LAB

(5 points)

Instructions: A map/diagram of Stonehenge can be found on the front and back of this laboratory exercise. After becoming familiar with Stonehenge and learning a little about its history, you will be shown where the sun rises at summer solstice and at winter solstice. These positions will be sketched on the back diagram of Stonehenge. The five trilithons that form the central horseshoe are marked one through five. They will serve as an easy reference to note other alignment locations. A north/south line has also been introduced on the map to help determine the other alignments that will be drawn. In the middle of this area an "X" has been placed to act as a reference position. Remember that these alignment lines must not only pass through one of the five trilithons, but also through an opening created by the 30 sarsen and lintel caps which form the outer ring. Otherwise the alignment will be incorrect. Use a pencil and ruler to make your sightings. On the diagram found on the next page:

1. Note the location of summer solstice sunrise with a straight line.
2. Note the location of winter solstice sunrise.
3. Sketch the line of sight for the winter solstice sunset. Label it.
4. Draw the alignment for summer solstice sunset. This one is a little tricky. Label it.

   Hint: The location of summer solstice sunrise is always exactly opposite to winter solstice sunset, and the position of winter solstice sunrise is always opposite to summer solstice sunset. Also, the rising and setting positions of the sun at the same solstice must always be symmetrical to the north/south line.



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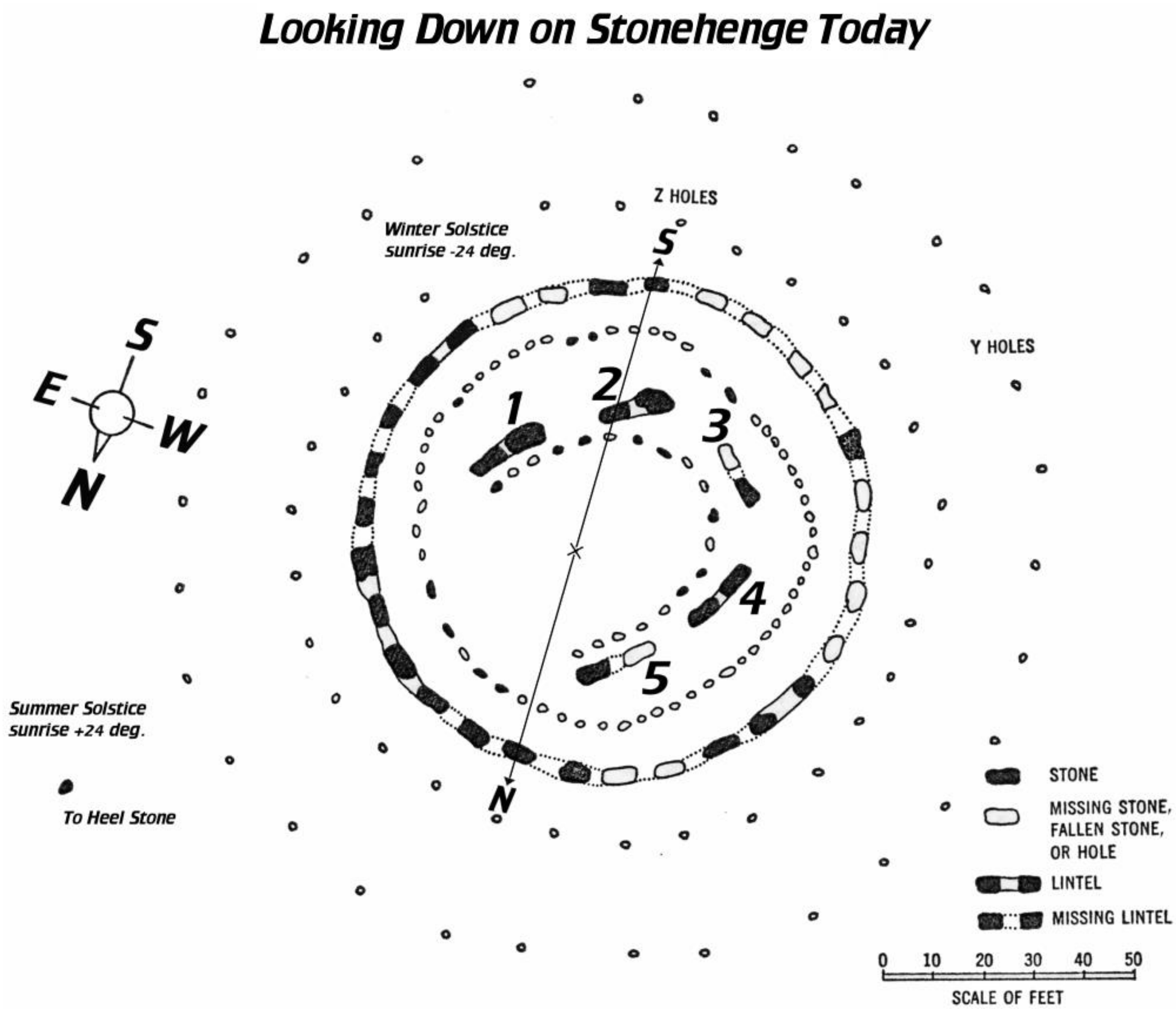
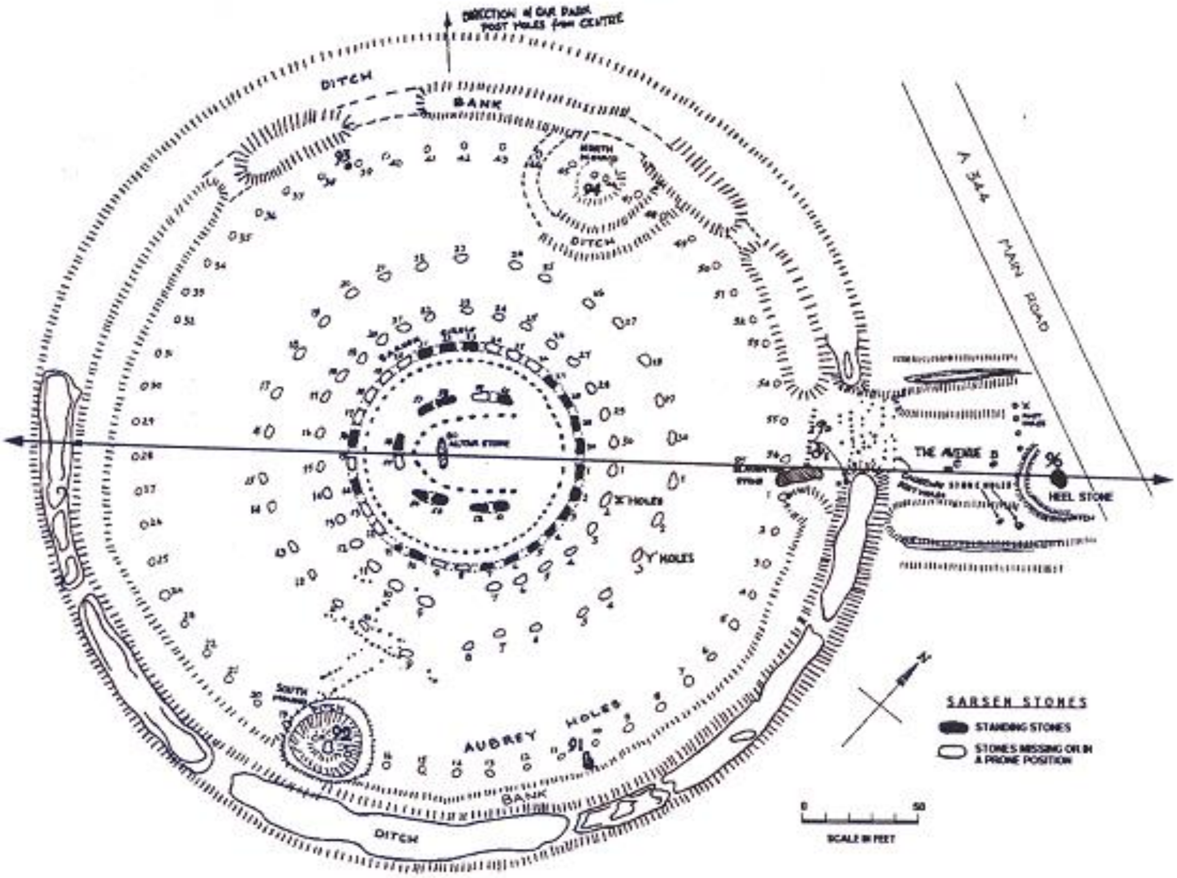
5. Add the number of "Y" plus "Z" holes. Divide that number by two and give some type of astronomical explanation for the answer you obtain.

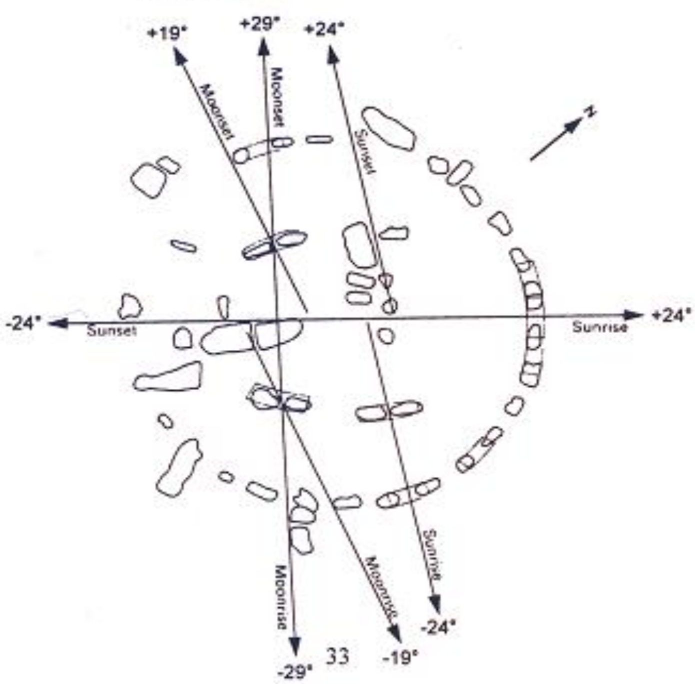
   Total "Y" holes _____ Total "Z" holes _____ Total "Y" plus "Z" _____ Average _____

   Significance? ____



MAP OF STONEHENGE





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NOTES

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THE MYSTERY OF CHACO CANYON

Detailing the research of Anna Sofaer, archaeoastronomer
Narrated by Robert Redford

1. ____________________ The Ancestral Puebloans chose Chaco Canyon to be the ... of their world (occurs during minute 4 of the video).

2. ____________________ There were … (a number) Great Houses constructed in Chaco with a total of 3000 rooms (5).

3. ____________________ At the center of the Chacoan world was ..., a structure which grew to cover over three acres, the size of the Roman Colosseum (5).

4. ____________________ Chaco Canyon lies in the state of … (8).

5. ____________________ The Chacoan culture covered an area of 95,000 square miles, roughly centering itself in a region of the United States called the … … (8).

6. __________/__________/__________/__________ The states that comprise the Four Corners are …, …, …, … .

7. ____________________ Does it appear as if the great houses of Chaco Canyon were occupied by large numbers of people or basically unoccupied (13)?

8. ____________________ A way of understanding the number of people living in the Great Houses is to look at the trash mounds. If little organic matter is found, it can be assumed that the pueblos were largely … .

9. ____________________ The trash mounds are composed mostly of … matter.

10. ____________________/____________________ The … …, a three slab structure that channels a shaft of sunlight which bisects a spiral on the summer solstice, is located on top of … …, the most prominent geological feature in Chaco Canyon (14).

11. ____________________ The S.D. (see answer above) shows the shaft of sunlight moving basically up/down/right/left during the 18 minutes that it is visible.

12. ____________________ The dagger is seen at noon when the sun has reached its highest altitude for the day and is moving in a horizontal/vertical direction (choose one).

13. _______________/_______________ The sun dagger is so intriguing because the dagger moves … while the sun is moving … .

14. ____________________ Fajada Butte was visible either directly or indirectly (from a ceremonial shrine) from most of the Great Houses in the region. Fires lit on top of Fajada Butte may have been used as a means for … throughout the Chaco Canyon region.

15. ____________________/____________________ The sun dagger calendar on Fajada Butte also marked the … … and the ... … (15).

16. ____________________ A … (general term for a picture which is a rock pecking) on Fajada Butte shows, according to archaeoastronomer Anna Sofaer, the half circle of Pueblo Bonito with an arrow along the mid-wall of the building pointing to the south and above to the sun at noon (19).

17. ____________________/____________________ At Pueblo Bonito the two long straight walls are exactly …-… and …-…, directions that have a special connection with the sun (20).

18. ____________________ The …-… wall divides exactly the seasons of the year and the day from the night (23).

19. ____________________ The sun rises due east and sets due west on the days of the autumnal and vernal … .

20. ____________________ The …-… wall divides the day, morning from afternoon. Pueblo Bonito may have been marking the middle of time. Three other buildings display this same relationship to the sun: Hungo Pavi, Tsin Kletsin, and Pueblo Alto (23).

21. ____________________ At Bonito there appears to be other astronomically significant features. For example, the shrine on the southeast corner of the building could have been used by a shaman as a location to mark the changes in the rising position of the … .

22. ____________________ This would have worked until … (a day and month), at which point distinctive markings on the horizon ceased to exist.

23. ____________________ After the aforementioned date, morning sunlight began entering a nearby second floor doorway projecting a mark upon the opposite wall. The splash of sunlight changed its position as the sun moved farther … .

24. ____________________ On the day of the … …, the rising sun projected the doorway into a corner niche.

25. ____________________ The calendar room in Pueblo Bonito seems to make sense, especially when considering that morning conditions in the canyon around winter solstice can get extremely … .

26. _______________/_______________ The calendar room would have functioned until late … (month) when the shaman would have taken his observations … .

Name ___________________________________ Date ______________ Moravian University

27. _______________/_______________ Astronomically, the shape of Pueblo Bonito suggests the path of the … or a quarter … .

28. ____________________ The plaza of Bonito in winter would have been warmer because the circular shape of the building would have focused the … … towards the center of the structure.

29. ____________________ The back walls of Pueblo Bonito, which may have been as high as six stories, would have had the energy of the winter sun striking them nearly … .

30. ____________________ In the summer these same walls would have been nearly … to the noontime sun.

31. ____________________ The southwestern section of the large plaza in Pueblo Bonito once boasted a huge Ponderosa pine tree. Astronomically, the tree could have functioned as a … .

32. ______________________________ Suggest a use or a purpose for Pueblo Bonito.

33. ____________________ At Chaco Canyon, if you follow the line of one building with respect to the sun, you come to another … (26).

34. ____________________ It seems as if the structures were designed to make Chaco the … place of the Ancestral Puebloan world (27).

35. ____________________ There were 15 great kivas at Chaco Canyon; each of these could hold over 400 people. One hundred smaller kivas at Chaco could hold between 50 to 100 people each. The largest great kiva in the canyon was … … (31).

36. ____________________/____________________ Great kivas were always astronomically aligned to the …-…, and …-… directions (32).

37. _________________________/____________________ In the case of Casa Rinconada, a window pointing towards the northeast directed a shaft of sunlight to a niche in the kiva wall at the time of … …. An east/west doorway aligned itself to the rising sun at the time of the … .

After describing the solar alignments at Chaco Canyon, the video proceeds to describe lunar alignments. The recording of these observations by the Ancestral Puebloans would have posed a level of difficulty which most archaeoastronomers are unwilling to accept. Enjoy the video from this point onward.

NOTES

Name ________________________________ Date _________________________________

Name ________________________________ Name _________________________________

Name ________________________________ Name _________________________________

TOP TEN REASONS

(Why You Would Want to Become an Ancestral Puebloan Priest)

Instructions: David Letterman and his "Top Ten Lists" segment became a legend to ***Late Night Show*** viewers. He did the skits for 30 years. Letterman took a topic usually involving an item in current events and created a humorous list about it based upon a theme. If you have never seen Letterman's Top Ten, Google it by typing "Letterman's Top Ten" and you will find hundreds of examples. In this exercise, each individual will develop a minimum of five **reasons why you would want to become an Ancestral Puebloan (astronomer) priest.** You must be factual but also add an element of humor to the way each reason is written. Your individual reasons may be graded (5 points). In class, teams will be created to produce a prioritized master list of top ten reasons from the individual lists that students have compiled. Much success!

10. ____

9. ____

8. ____

7. ____

6. ____

5. ____

4. ____

3. ____

2. ____

1. ____

August 6, 2019

Below can be found two examples of Letterman's Top Ten.

Top Ten Signs You Had a Bad Valentine's Day

10. You got a ticket to Hawaii. Unfortunately, it's a bus ticket.

9. There was hanky, but no panky.

8. It was just you, your date, and his parole officer.

7. Only person you saw naked was your mother-in-law.

6. You found out your date "Sherry" was really "Sherlock."

5. Night ended with you vomiting in a Red Lobster parking lot.

4. Instead of cupid, you were shot by a Latin King as a part of a gang initiation.

3. Somehow you ended up in a Mexican prison.

2. During a moment of candlelit passion, your hairpiece caught fire.

1. When your dinner came out, so did your husband.

Top Ten Signs You're in a Bad Relationship

10. You call her "sweetie." She calls you "that guy whose food I'm poisoning."

9. You share the same prison cell.

8. I'm sleeping with your wife.

7. Your husband comes home with a new dress for you and another one for himself.

6. You sleep in separate beds, in separate rooms, in separate houses, in separate states.

5. He has spent the last three-and-a-half years fleeing from cave to cave.

4. She watches "Desperate Housewives" for ideas on how to cheat.

3. Your spouse is late for your anniversary because "the gay bar didn't have a clock."

2. Her response to your marriage proposal is, "I guess."

1. You just married a Kardashian.

NEWSPAPER ASSIGNMENT

Purpose: This exercise will help to solidify concepts pertinent to an understanding of archaeoastronomy and the seasons.

Instructions: You have been assigned by your newspaper editor to interview Dr. David Moyer, an archaeoastronomer, about a new discovery which his team has just made. You are to file a report on the work he has done. Make sure that the following seven items noted below are included. When a concept has been covered, indicate this with the appropriate number in front of the sentence or paragraph. Reporters do not have to write about the concepts in any particular order.

1. The site… Give the site a name.
2. A description of the site… Describe the site. Use colorful adjectives, the five senses.
3. How the alignment(s) functions… How does the site function as an astronomical calendar?
4. Some basic information about who the Ancestral Puebloans were…
5. A definition for archaeoastronomy…
6. An explanation for the seasons…
7. The effects of the seasons as witnessed in a mid-latitude region, such as Bethlehem, PA.

The site, which will be chosen by students, can be real or fictitious; however, the method for creating the calendar must fit the guidelines for Ancestral Puebloan settlements as discussed in class.

Template: Use the style sheet for the Mini-Term Paper which can be found in the beginning of this textbook. This is a content driven assignment, which means that I am looking for correct facts, grammar, spelling, and punctuation. Footnotes, a bibliography, and a title page are NOT necessary, since all information needed is contained in Session Three. The length of the presentation should fall between 500-800 words. This presentation must be typed, double spaced, using 14 point New Times Roman font with one inch margins. Remember, the archaeoastronomy pictures are online at www.astronomy.org. You may work with one partner. Total point value is 20.

Due Date:

Sample paragraph: Please see a sample story line that you can use, word for word, to begin your presentation.

NEW ALIGNMENTS SHOW SOPHISTICATION OF ANCESTRAL PUEBLOANS

Recently discovered astronomical alignments have shown a new level of sophistication among Ancestral Puebloan Indians who lived in the southeastern corner of ________________ over 700 years ago. The discovery was made at ____ by Princeton astronomer, Dr. David Moyer, and a team of six undergraduate students. Moyer's group found that certain

could have been used to monitor the passage of the seasons, and thereby, establish a calendar for the planting and harvesting of crops. The Ancestral Puebloan inhabited this region… You continue from here.

ANCESTRAL PUEBLOAN WORD LIST

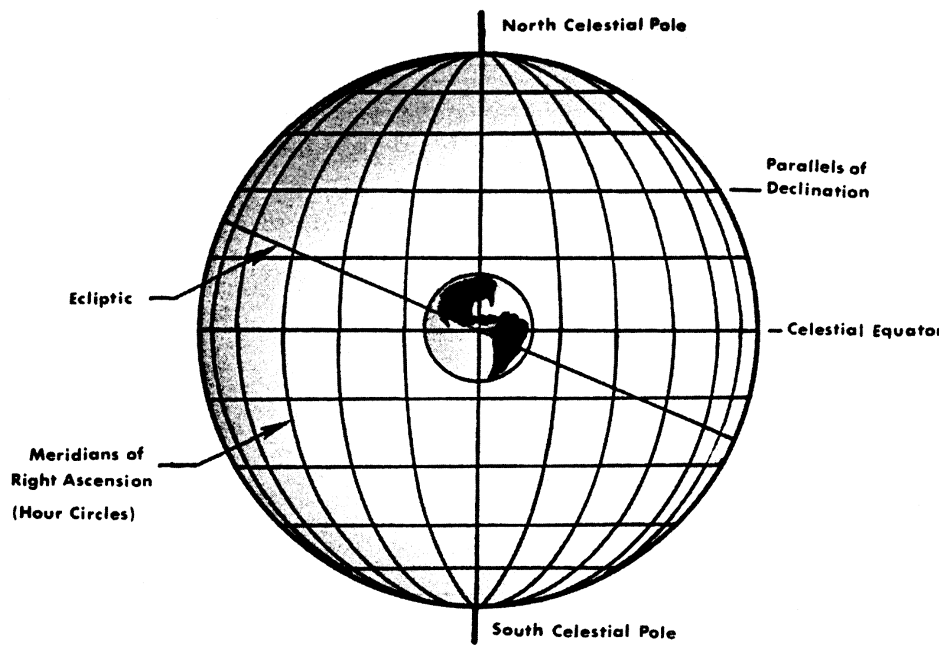
Acoma Pueblo	ecliptic	ports
Albuquerque, NM.	elliptical orbit	potsherds
Anasazi	faces NE, faces SW	pueblo
Ancestral Puebloans	Fajada Butte	Pueblo Alto
archaeoastronomy	Fajada Wash	Pueblo Bonito
archaeology	foresight	Pueblo del Arroyo
architecture	Four Corners	Pueblo Indians
Arizona	Gallo Campground	Puebloan Society
astronomer priests	great house	Red Mesa
autumnal equinox	Halley's Comet	right ascension
axial tilt	helical rising of object	Rio Grande Valley
axis	Hopi	roadways
Aztec Nat. Monument	Hovenweep Castle	Rt. 57
Balcony House	Hovenweep Nat. Mon.	Rt. 550
backsight	I-40	Salmon Ruins
beans	indirect sun	San Juan River Basin
cannibalism	hunter gathers	shade during high sun
cardinal points	Jackson Stairway	solstitial marker
Casa Rinconada	kiva	south
Chaco Canyon	masonry styles	South Gap
Chaco Culture Nat	matriarchal	Square Tower Ruin
Historical Park	measuring shadow lengths	squash
Chaco Wash	Mesa Verde Nat. Park	stairway
Chacoan	moon	stationary observer, moving sun
check dam	moving obser., stationary sun	Square Tower Ruin
Chacra Mesa	Nageezi, NM	strategic
Chetro Ketl	Navajo	summer solstice
Cliff Palace	New Mexico	sun
Colorado	niche	sun dagger
Colorado Plateau	nomadic	sun room
Colorado River	north	supernova pictograph
corn	North Mesa	Tsin Kletsin
corner windows	North Road	Una Vida
declination	north-south alignment	unit house
direct sun	north-south wall	Utah
directional alignment	outlier	variation in length of day
doorways	passive solar	vernal equinox
east	Penasco Blanco	west
east-west alignment	petroglyph (rock pecking)	West Mesa
east-west wall	pictograph (rock painting)	Wijiji
	pit house	winter solstice
		Zuni Pueblo

THE EQUATORIAL COORDINATE SYSTEM

We want to know **where** the individual objects of the universe are in space relative to each other, i.e., we want to discover the geometry of the universe, and the equatorial coordinate system will help us attain that objective. The equatorial coordinate system provides us with a system for measuring the universe as it is seen naturally from Earth.

As a system of measurement, the equatorial coordinate system represents a refinement over the ancient method of mapping the sky in terms of constellations. Through the use of constellation, the ancients were able to divide the night sky into broad areas (the north and south circumpolar regions, the equatorial region, and the zodiac) and into the 88 sub areas represented by the constellation figures themselves. But, given only the constellations, it is impossible to define the relative positions of the celestial bodies with any degree of precision. Whereas the constellations define the location of **groups** of stars, the equatorial coordinate system allows us to define the location of **individual** stars.

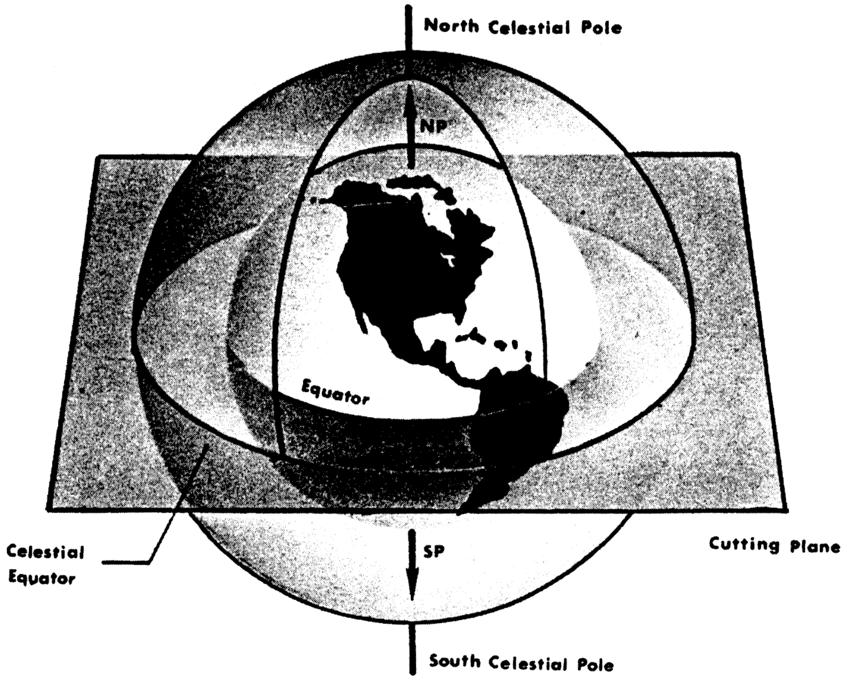
Using the equatorial coordinate system, we can specify the position of the individual stars on the surface of the celestial sphere just as the Earth's system of latitude and longitude enables us to specify an individual's position on the surface of the Earth. On Earth, we specify position by referring to a system of meridians of longitude, parallels of latitude, and poles. The equatorial coordinate system is composed of analogous features, although differently named.



The Equatorial Coordinate System

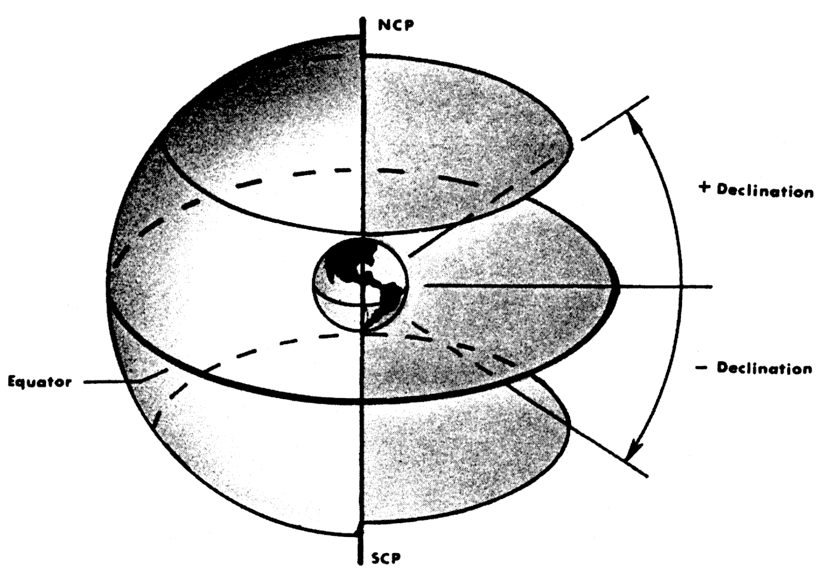
The essential features of the equatorial coordinate system are the celestial equator, celestial poles, parallels of declination, right ascension circles, the vernal equinox, and the ecliptic.

The Celestial Equator and Celestial Poles



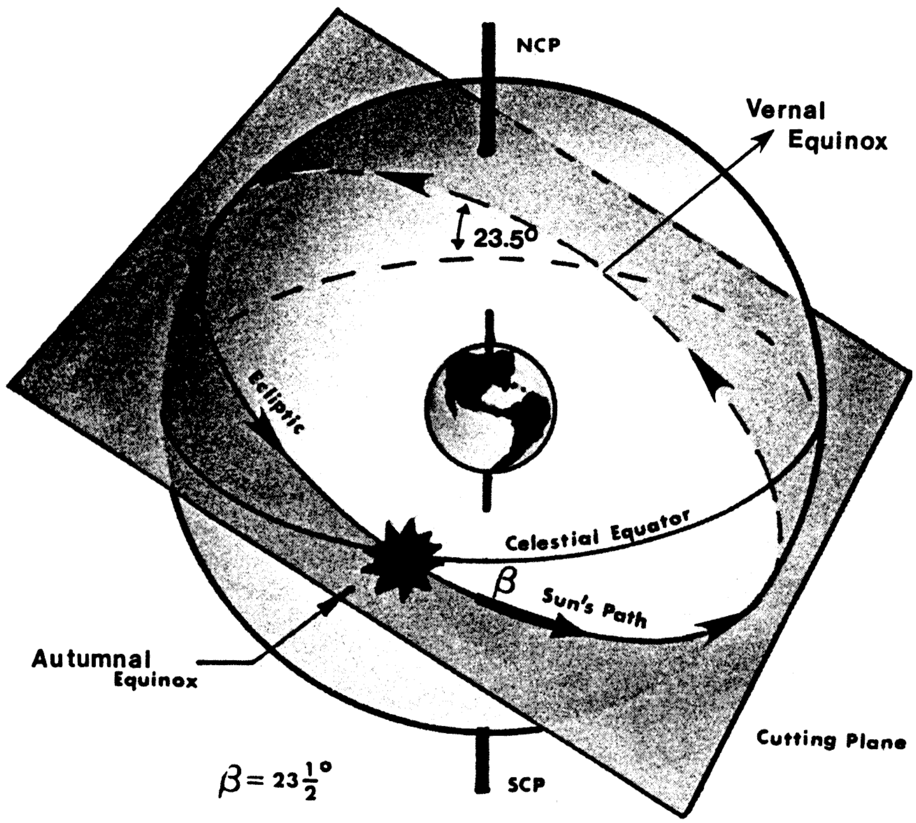
The **celestial equator** is a projection of the Earth's equatorial plane to the surface of the celestial sphere. The celestial equator could be formed by passing a plane (flat) surface through space which cuts both the Earth and the celestial sphere exactly in half, at right angles to the Earth's axis of rotation. The north and south **celestial poles** are the piercing points formed by an extension of the Earth's axis of rotation to the surface of the celestial sphere.

Parallels of Declination



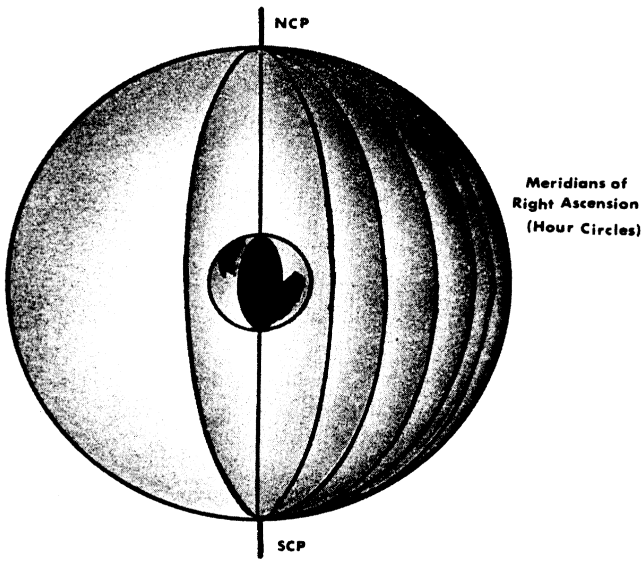
Lines drawn parallel to the Earth's equator are called parallels of latitude, while lines drawn parallel to the celestial equator are called **parallels of declination**. Parallels are useful when considering displacement between the equator and the poles, i.e., when measuring north and south.

The Ecliptic and Vernal Equinox



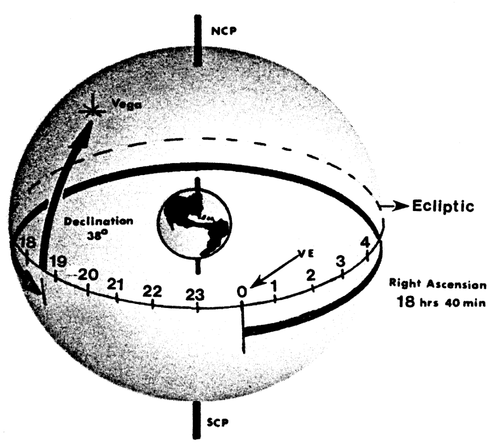
The ecliptic helps us specify the exact position of the sun relative to the stars. As previously discussed, the ecliptic marks the path of the sun relative to the stars during the course of a year. The ecliptic, like the celestial equator, divides the celestial sphere exactly in half, but at an angle of 23 ½ ° to the celestial equator. The point of intersection between the ecliptic and the celestial equator is called the **vernal equinox**. The vernal equinox marks the celestial position of the sun on the first day of spring.

Hour Circles



Lines of **right ascension**, sometimes called **hour circles**, are used when measuring east or west on the surface of the celestial sphere. Right ascension circles extend from pole to pole on the surface of the celestial sphere in the manner of longitude circles on Earth.

How the System Works



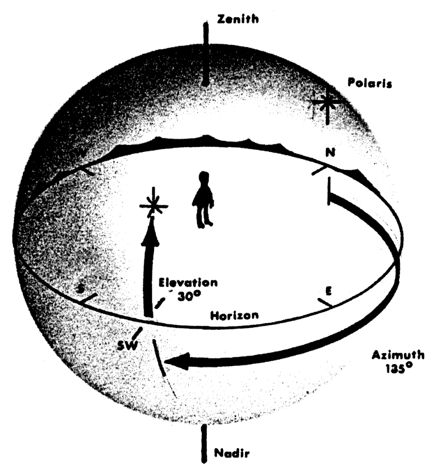
To aid us in specifying positions on the surface of the celestial sphere, in addition to the constellation, we now have the system of lines and points represented by the equatorial coordinate system. The system is simple to use since the apparent celestial position of any star can be specified by only **two** coordinates, one giving the position of the star north or south of the celestial equator, and another giving the star's position east of the zero right ascension circle. The star Vega in the constellation Lyra, for example, has a declination of +38°, and a right ascension of 18 hours 40 minutes. The diagram below illustrates the method of measurement on the celestial sphere.

Right ascension is almost always measured east of the vernal equinox in hours, minutes, and seconds. Each hour of right ascension corresponds to 15° of displacement on the celestial sphere; therefore, Vega is located 280° east of the zero hour circle (80° west).

Declination is always measured in positive (north) or negative (south) degrees, minutes, and seconds from the celestial equator. Vega, therefore, is located 38° north of the celestial equator, but it is written as +30°.

How We Link the Sky and Earth

We can locate the position of a star on the celestial sphere by specifying its equatorial coordinates. One can also specify positions on Earth by using the Earth's coordinate system. Now, how can we specify the positions of the stars relative to the surface of the Earth. How, for example, can a person in San Francisco determine what is overhead, or in some other direction, at any given time? The system that has been devised to suit this purpose is called the **horizon system of coordinates**. The illustration to the right shows the simplicity of the system.



In the horizon system of coordinates known as altitude and azimuth, we specify the position of a star relative to the Earth's surface by stating the star's place relative to our local horizon in terms of its **altitude** (elevation) and **azimuth** (direction). The altitude of a star is simply the angle between the star and the observer's horizon; and its azimuth is simply the angle between a point due north of the observer and the star, measured eastward along the horizon. Thus, to find a star whose altitude and azimuth are 30° and 135°, respectively, an observer should look 30° above the horizon in the southeast.

Note that altitude and azimuth are always dependent upon the observer's position on Earth and the observer's local time since the celestial sphere and the Earth are always in motion with respect to each other. At any given instant in time, and at any given point on the Earth's surface, a given star can have only one altitude and azimuth. The horizon system of coordinates is, therefore, very useful to navigators. A navigator, knowing the local time, can determine his/her position on Earth by measuring the altitude and azimuth of a star whose vertical position over the Earth's surface can be obtained by a sextant or some other angle measuring device.

NOTES

A BRIEF REVIEW OF COORDINATE SYSTEMS

Latitude and Longitude

In order to pinpoint locations on the surface of the Earth, a coordinate system which is termed latitude and longitude had been devised. **Latitude** is an angular measurement made from the Earth's center, northward or southward from the equator, along a meridian circle to the location in question. **Longitude** is an angular measurement also made from the center of the Earth, east or west from the Prime Meridian, along the equator to the meridian circle which contains the position. The range of longitude is from 0° to 180° east or west of the Prime Meridian, while the range of latitude is from 0° to 90°, north or south of the equator. In both cases the hemisphere of the position must be stated. For example, Allentown, PA is located at approximately 40° *north* latitude and 75° *west* longitude. Allentown is in the northern and western hemispheres.

The Equatorial System: Right Ascension and Declination

If you imagine the grid of latitude and longitude superimposed on a transparent sphere, which is surrounded by a larger sphere (the celestial sphere, which is really the sky), you are ready to understand how the equatorial coordinate system is formed. This system is used by astronomers to locate objects in the sky. If a flashcube were placed in the inner transparent sphere and fired, the light of the bulb would radiate outward to the celestial sphere, casting the shadows of latitude and longitude onto it. Where these shadows would fall, a new **"equatorial" coordinate system** would be formed called **right ascension and declination**. The circles of **latitude** would now correspond to **declination**. Instead of being measured north or south of the equator, they would be measured north or south of the celestial equator as either positive or negative angles respectively. **Longitude** would become meridians of **right ascension** measured eastward from the intersection of the celestial equator and the ecliptic. The **ecliptic** represents the path of the sun in the sky as the Earth revolves around this star. The intersection position of the celestial equator and ecliptic is known as the **vernal equinox**, and it is the location of the sun at the first moment of spring. This is also the origin of the equatorial coordinate system. Right ascension is always measured along the celestial equator eastward from the vernal equinox. There is no westward component as in the terrestrial system of longitude.

Right Ascension and Sidereal Time

Right ascension positions are usually measured in hours, minutes, and seconds. The coordinates of the system form a sidereal (star) clock composed of 24 hours which is equal to the interval of one Earth rotation. This time system is called sidereal time. Twenty-four hours of sidereal time (literally star time) is about four minutes less than the solar time measured by clocks throughout the world. In other words, one Earth rotation equals 23 hours, 56 minutes of clock time. This 23 hour, 56 minute interval is divided into its own 24-hour system which is called a sidereal day.

NOTES

THE SEASONS

Most people believe that the seasonal variations that we experience are the result of our changing distance from the sun. Nothing could be farther from the truth. Although the Earth's distance from the sun varies by about three million miles, we are closest to the sun in winter and farthest from our daystar during the summer months, just the opposite of what would be normally expected. The seasons are the result of changes in the amount of solar energy which is received at the Earth's surface. The change in the Earth-sun distance plays a minor role. Instead, these energy changes come about because the Earth's axis is tilted in relation to its orbital plane which is called the ecliptic. The Earth's axis is the imaginary line about which our planet rotates. The measure of Earth's axial tilt is referenced from the perpendicular to the ecliptic. It is generally stated in the following manner. The Earth's axis is tilted 23-½° from the perpendicular to the ecliptic. Earth's axis pointing in the same direction is another factor responsible for creating seasonal changes. Currently the axis is pointing in the direction of the North Star, also called Polaris. This is why Polaris represents the hub of the wheel about which the sky pivots as Earth rotates. Expressed in another way, the ecliptic is tilted to the plane of the Earth's equator by 23-½°. Our orbital motion makes the sun move eastward among the stars. Our axial tilt also causes the sun to move northward or southward with respect to the equator shining directly over the Tropic of Cancer on the summer solstice, the equator on the equinoxes, and the Tropic of Capricorn at the time of our winter solstice. Three yearly cycles can be easily monitored as the seasons progress:

1. **<u>The altitude of the sun changes</u>:** The sun reaches its highest position above the horizon at local noon each day. In Allentown, PA when the sun is at its most northerly position, with respect to the equator, its altitude at noon is at an extreme of 73º. This occurs on the first day of summer. In Allentown, the sun is never directly overhead. On the first day of winter, the sun is as far south of the equator as it can be found and it achieves its minimum altitude of 26º at noon as seen from the city.
2. **<u>The duration of daylight changes</u>:** The longest day of the year occurs for the northern hemisphere when the sun is at its most northerly position with respect to the equator. This marks the first day of summer. In Allentown, the sun rises in the northeast taking approximately 15 hours to cross the sky before setting in the northwest. The path that the sun takes from rising to setting is longest at summer solstice. Therefore, the day must also be at its longest because the earth rotates at a uniform rate of 15 degrees/hour. When the sun is at its greatest deviation south of the equator, the day is the shortest. This marks the beginning of winter. In Allentown the sun rises in the southeast, and about nine hours later, it sets in the southwest.
3. **<u>The positions of sunrise and sunset change</u>:** For observers in Allentown on the first day of summer, the sun rises as far to the north of east and sets as far to the north of west as it can for the year. The sun is positioned at its maximum extreme north of the equator. When the sun is positioned as far to the south of the equator as it can move, on the first day of winter, it rises as far to the south of east and sets as far to the south of west as it can for that location. The sun, therefore, changes its daily rise and set positions with respect to the horizon.

In winter, the northern hemisphere leans back from the sun. The daily duration of sunshine is restricted, and the sun is lower at noon. The sun's energy strikes the ground at a shallower angle, and thus less energy is received per unit area. The temperatures generally become colder. In summer, the northern hemisphere is tilted toward the sun. Not only is the daily duration of sunshine longer, but the sun also climbs to a higher altitude in the sky, so that its energy strikes our position more directly, and we receive more energy per unit area. All of these effects result from the tilt of Earth's axis and its consistent pointing direction.

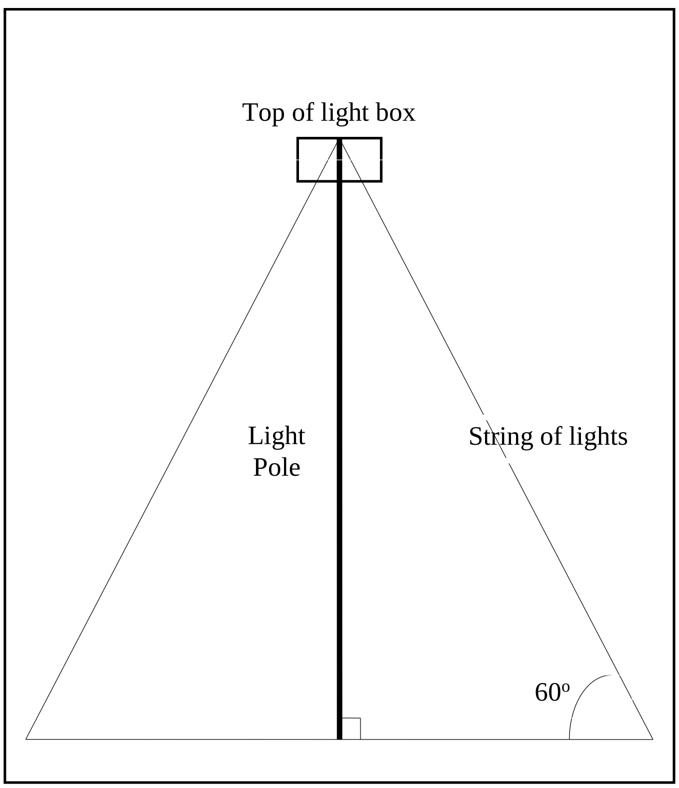
NOTES

LIGHT MY POLE
(5 points)

Philosophy students at Moravian University, have been planning for months to decorate, in the shape of a Holiday tree, one of the light poles in the PPHAC Commons. Their goal has been to make the campus look a little more festive by stringing cables with lights on them from the top of one of the light poles to the ground. The cables will be extended downward and meet the ground at an angle of about 60º. As a safety precaution, electricity to the lights will be provided from the top of the pole at the location of the disconnected lamp. Everyone (except University officials) has been really excited about the project. The student steering committee under the leadership of Cody Yarnall even found several fabricators willing to manufacture the proper length of lights in one string, if the committee could supply them with the height of the pole. Students will also need to rent a cherry picker that will be able to reach to the top of the light to assemble the tree.

Since the students need to know the height of the pole in order to provide this information to the manufacturer of the lights, Cody contacted Moravian officials in Colonial Hall and in maintenance. Unfortunately, they have been unwilling to provide this datum. The committee and Cody have turned to students in Gary Becker's EASC-130 PM/PN classes to provide a solution to their dilemma.

To solve this problem, here are some of the items or concepts you may want to consider utilizing: yardstick, tape measure, pencil, paper, trigonometry, algebra, or just plain geometry (making a scaled drawing), the sun, moon, shadows, altitude of the sun/moon and the time when the measurement was made, similar triangles, a calculator (for faster computation). A drawing of the problem is sketched below.



TEAM'S SOLUTION ON BACK
Name of Team:

____

Team Members (3-6 individuals):

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

Light My Pole
Team solution

PLANET PLOTS/MOON PLOTS

(10 points/30 points)

Introduction: Positions on the Earth's surface can be accurately defined by a coordinate system called latitude and longitude. **Latitude** (*climb the rungs of a ladder*) is an angular measurement made from the Earth's center, proceeding either **northward** or **southward** from the equator along the vertical circle (*circle of longitude*) which contains the place, to the place. **Longitude** (*long great circles*) is an angular measurement also made from the center of the Earth, **eastward** or **westward** from the Prime Meridian, along the equator to the vertical circle which contains the place. The range of longitude is from 0^{o} to 180^{o}, east or west, while the range of latitude is from 0^{o} to 90^{o}, north or south. Specifying a position on the surface of the Earth requires that the hemisphere of latitude, either north or south, or the hemisphere of longitude, either east or west, be specified.

If you imagine the grid of latitude and longitude on a transparent sphere which is surrounded concentrically by a larger sphere (called the celestial sphere), you are ready to understand how the equatorial coordinate system is formed. If a strobe were placed in the inner transparent sphere and fired, the light of the bulb would radiate outward to the celestial sphere, casting the shadows of latitude and longitude onto it. Where these shadows would fall, a new *equatorial* coordinate system would be formed called right ascension and declination. The circles of **latitude** would now correspond to **declination**. **Declination**, instead of being measured north or south of the equator, would be measured north or south of the celestial equator as either positive or negative angles respectively. **Longitude** would become vertical circles of **right ascension** measured eastward from the intersection of the celestial equator and the ecliptic. This position is known as the **vernal equinox**, and it marks the location of the sun at the first moment of spring. Right ascension positions are measured in hours, minutes, and seconds, and form a time system composed of 24 hours which is equal to the interval of one Earth rotation. This time system is called **sidereal time** or literally star time. Twenty-four hours of sidereal time is about four minutes less than the solar time measured by clocks throughout the world.

Purpose: To gain familiarity with the equatorial coordinate system of right ascension and declination by plotting the positions of various astronomical objects.

Procedure:

1. Use a sharp pencil to complete this laboratory exercise.

2. Plot the given right ascension and declination positions of the planets, moon, and sun on the long equatorial coordinate sheet which has been given to you. Note that the smallest increments of declination on the map are one degree while the smallest increments of right ascension are equal to five minutes of arc. The positions to be plotted on the star chart are calculated for the date of ___________________________. They will be given to you by your instructor, and should be recorded in the proper locations found on the next two pages of this laboratory exercise.

3. In order to plot an object, position the edge of a sheet of paper at the correct right ascension location inscribed at the top and bottom of the star map. Draw a short line segment centered on the ecliptic. The **ecliptic** is represented by the curve that bisects the sheet and is positioned symmetrically with the celestial equator, 0^{o} declination. Since all

of the planets and the moon lie near the ecliptic, the planet's or moon's true position should be somewhere near this path.

4. Repeat the procedure, only this time positioning the edge of the paper along the correct declination markings found along the vertical axes of the map. There are numerous vertical axes on the map which contain the declination increments.

5. Mark the position of the object with a small, *lightly* inscribed cross. **Do not put a circle at the intersection position.** To receive credit for the plot, the position of intersection will have to fall within the boundaries of a small circle inscribed on the instructor's star map.

6. Label the position of the planet, sun, or moon so it can be readily identified. In the case of the moon's position, identify each location of the moon by noting the date next to the cross.

OBJECTS TO BE PLOTTED

Date:

Object	*Right Ascension*	*Declination*
Sun		
Moon		
Mercury		
Venus		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		

P O S I T I O N S O F T H E M O O N

Date	Right Ascension	Declination
March 20, 2024	09h 10m	+20° 58m
March 21	09h 57m	+16° 35m
March 22	10h 41m	+11° 36m
March 23	11h 24m	+06° 14m
March 24	12h 05m	+00° 38m
March 25	12h 47m	-05° 00m
March 26	13h 29m	-10° 30m
March 27	14h 14m	-15° 34m
March 28	15h 01m	-29° 20m
March 29	15h 51m	-24° 12m
March 30	16h 45m	-27° 02m
March 31	17h 42m	-28° 35m
April 1	18h 38m	-28° 41m
April 2	19h 38m	-27° 09m
April 3	20h 37m	-23° 58m
April 4	21h 35m	-19° 17m
April 5	22h 31m	-13° 23m
April 6	23h 58m	-06° 36m
April 7	00h 19m	+00° 37m
April 8	01h 13m	+07° 49m
April 9	02h 07m	+14° 30m
April 10	03h 05m	+20° 14m
April 11	04h 05m	+24° 36m
April 12	05h 06m	+27° 20m
April 13	06h 07m	+28° 20m
April 14	07h 06m	+27° 40m
April 15	08h 02m	+25° 33m
April 16	08h 54m	+22° 16m
April 17	09h 42m	+18° 05m
April 18, 2024	10h 27m	+13° 15m

Answer the questions on the following page.

Positions of the Moon, continued

Name ______________________________ Date _________________ Moravian University

1. Look at the location of the moon on August 21, 2017. Also look at the location of the sun on the same date. These dates are indicated along the curved path of the ecliptic. Astronomically speaking, is anything important about to happen? If so, what will it be?

   ___________________ Yes or No... Will an important astronomical event be happening on August 21? If you answered, "yes," continue to the next question.

   ___________________ What is the name of this event?

2. The plots of the moon should look like they are evenly spaced so that a smooth curve should be able to connect to each of the points. This is one way of determining whether your moon plots might have embedded errors within them. If you examine the points very carefully, there is an area of the curve where the spacing between points is slightly greater, and another area where the moon's spacings are slightly closer together.

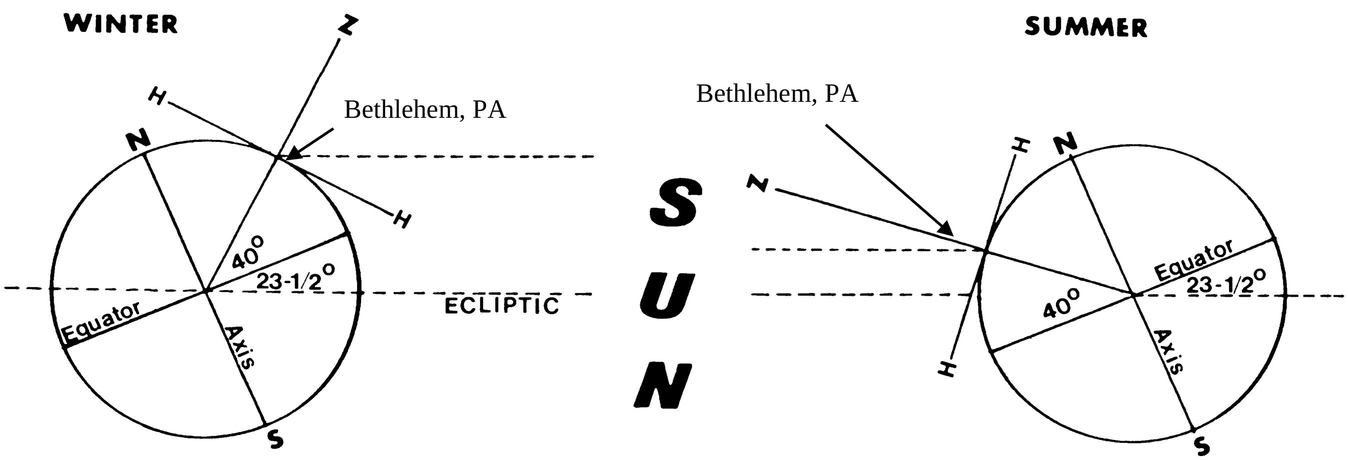
   __________________ Indicate the date where the spacings look to be at their greatest. During this time the moon is at **perigee** or at its closest distance from the Earth, and is moving at its fastest orbital speed. **Label the perigee spot on your map.**

   __________________ Indicate the date where the spacings appear to be the tightest. During this period the moon is at **apogee**, and is farthest from the Earth. **Indicate the apogee location on your map.**

3. In two locations on the map, the moon is crossing the ecliptic. These crossing positions are called **nodes**. In one of the locations, the moon is moving from below the celestial equator to above the celestial equator. This is called the **ascending node**. In the other situation, the moon's position changes from above the celestial equator to below the celestial equator. This is known as the **descending node**. Connect the lunar positions on either side of each node and identify the crossing positions on your map.

UNDERSTANDING THE SEASONS

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



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

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

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

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

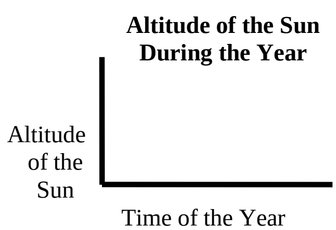
Sun's Location from Bethlehem, PA, 40° North Latitude

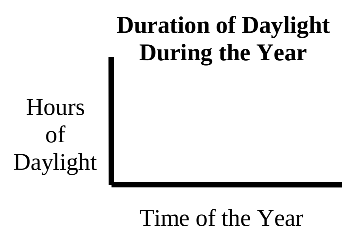
Date	**Sunrise Azimuth**	**Altitude of the sun at Noon**	**Relative Flux** **Sine of Alt.**	**Sunset Azimuth**	**Duration of Daylight**	**RA of the Sun**	**Dec. of the Sun**
March 21							
June 21							
September 21							
December 21							

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

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

66 ½° N
40° N
23 ½° N
0°
23 ½° S





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

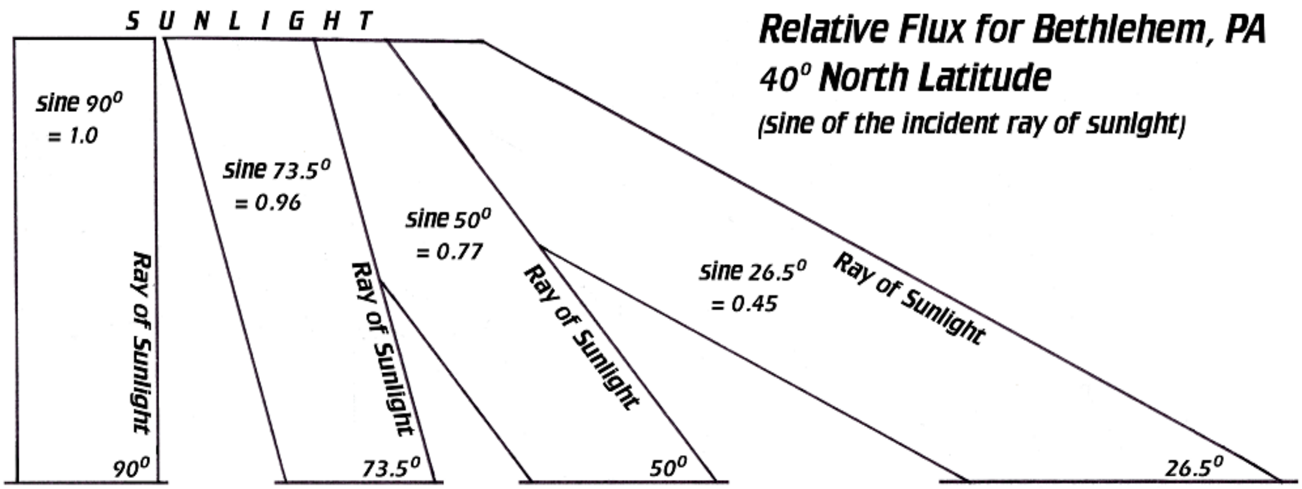
All five curves should be plotted on the same graph and using a key, identified with respect to latitude. You should plot 13 points for each latitude, repeating March 21. Draw smooth curves through the respective data points for each separate latitude sequence. Use the tables of data found in the back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

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

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

Calculating the Relative Energy Flux at Noon

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



Data for Graphing the Seasons

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

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

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

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

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

Name ________________________________ Date _______________ Moravian University

QUESTIONS DEALING WITH THE ALTITUDE GRAPH

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

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

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

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

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

____

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

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

____

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

____

____

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

____

____

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

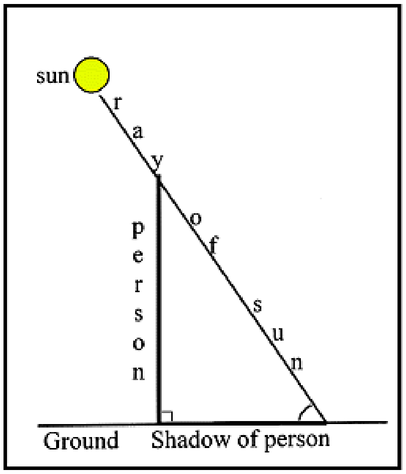
____

____

____

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

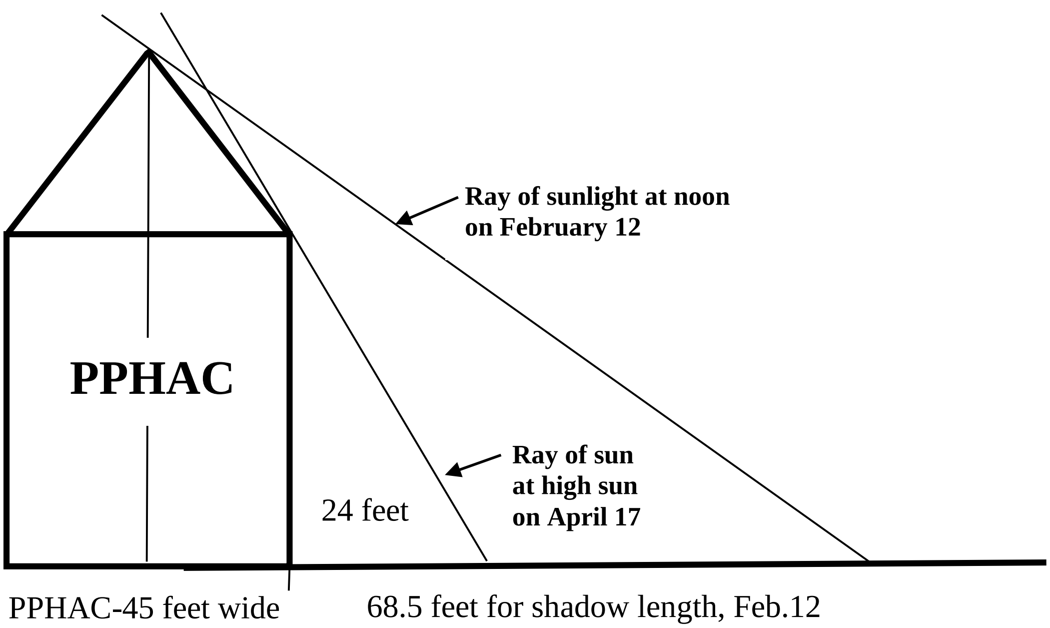
11. Determine mathematically or by geometric construction (see the diagram on the next page) the length of the shadow that you cast in a standing position at noon on the first day of spring. Consider your location to be at Moravian University in Bethlehem. PA. In a geometrical construction, you must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



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

   a. What is the rappel length from a point midway between PPHAC's two sides? ________________

   b. Will the student have enough rope to make a successful descent? __________



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

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

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

QUESTIONS CONCERNING THE SUNRISE/SUNSET GRAPH

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

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

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

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

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

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

NOTES

BASIC ARCHAEOASTRONOMY WORD LIST

Instructions: Students should read this vocabulary list prior to the presentation about the astronomy of Chaco Canyon to make the lesson more understandable.

1. **Acoma:** Sky City… Puebloan tribe closely associated with the Chacoan Phenomenon.
2. **Anasazi:** Navajo word meaning "ancient enemies." An out-of-date term used to describe the indigenous people of the Four Corners region and beyond who lived in buildings and towns.
3. **Ancestral Puebloans:** The accepted term used by archaeologist to describe the indigenous peoples of the Four Corners area whose ancestors lived in masonry structures.
4. **Archaeoastronomy:** A scientific discipline which unites the fields of archaeology and astronomy to decipher information regarding how ancient cultures used the sky for their practical benefit.
5. **Archaeology:** A scientific discipline which tries to understand ancient cultures from the artifacts and architecture which their inhabitants left behind.
6. **Arroyo:** An intermittent stream, often dry, but capable of transporting large volumes of water during heavy rains.
7. **Astronomer priests:** Early sky watchers who kept the calendar and formulated religious cults centered on heavenly deities, such as the sun, moon, and planets.
8. **Autumnal Equinox:** The position in the sky where the sun crosses the celestial equator moving in a southward direction. It usually occurs around the 21st of September. When the sun is located at either one of the equinoxes, the length of night and day are equal everywhere on Earth, except near the poles.
9. **Axial tilt:** The inclination of the imaginary line about which an object rotates to the perpendicular to that object's orbital plane. The Earth's axial tilt is 23.5 degrees from the perpendicular to the ecliptic.
10. **Axis:** The imaginary line about which an object rotates.
11. **Aztec Ruin:** The largest northern Chacoan outlier. It was located on the confluence of the San Juan and Animas rivers in the town of Bloomfield, NM. The town bridged the Chacoan Phenomenon and the Mesa Verde period.
12. **Balcony House:** Mesa Verde National Park… A well preserved pueblo set on a high ledge noted for its balcony structures and strategic placement. Balcony House has 45 rooms and two kivas.
13. **Backsight:** The position from which observations are being conducted.
14. **Cannibalism:** The ritualistic practice of people eating other people… It was practiced by Ancestral Puebloans near the end of the Chacoan Phenomenon as a form of subjugation and possibly even nutrition.
15. **Cardinal Points:** The four principal directions: north, east, south, and west.
16. **Casa Rinconada:** Spanish for "house within corner…" The largest of the excavated great kivas in Chaco Canyon. It was constructed around 1060 AD on a platform of dirt built-up at the site by the Chacoan laborers.
17. **Chaco Culture National Historical Park:** Ninety-five miles NW of Albuquerque, NM, this area housed the greatest concentration of wealth and architecture of the Chacoan Period.
18. **Chaco Phenomenon:** The period between 850AD to the early 1100s when the influence of the Ancestral Puebloan people living in Chaco Canyon dominated the Four Corners region.
19. **Chaco Wash:** The largest arroyo (intermittent stream) of Chaco Canyon.

20. **Check Dam:** An obstruction consisting of rocks and sticks along an arroyo used to slow down the velocity of runoff water for its collection as well as deposited soil.
21. **Chetro Ketl:** The largest great house with respect to surface area in the Chacoan world. It was built about one half miles to the east of Pueblo Bonito in the mid-1000s on an east-west solar alignment with Pueblo Bonito and Kin Klizhin.
22. **Cliff Palace:** Mesa Verde National Park… The most famous cliff dwelling (town) of the Ancestral Puebloan world.
23. **Corner Windows:** Large openings constructed at the corners of rooms that may have been used to tunnel sunlight for calendar-keeping purposes (calendar rooms/sunrooms).
24. **Declination:** The angular measure of an object north or south of the celestial equator. It is measured in degrees "+" (positive-north of the celestial equator) or "–" (negative-south).
25. **Dendrochronology:** The dating of structures through the study of tree ring patterns found in wood excavated at archeological sites. The wood is compared to a continuous set of standard tree rings which date from the present to antiquity.
26. **Direct Sun:** Sunlight that strikes the ground at a steep angle, therefore providing a great amount of insolation.
27. **Ecliptic:** The plane of the Earth's orbit projected into space. The eastward path of the sun across the sky produced by the revolution of the Earth around the sun. The ecliptic is inclined 23 ½° from the plane of the celestial equator.
28. **Elliptical orbit:** The revolution of a body in an oval-shaped path.
29. **Fajada Butte:** The geological feature in Chaco Canyon that may have represented one of the spiritual centers of the Chaco Phenomenon. All Chacoan great houses and outliers had direct or indirect lines of sight to this feature. Near the top of Fajada Butte, the sun dagger was fashioned from three pancake-shaped slabs of rock that fell from the butte's summit walls.
30. **Foresight:** A distant mountain, geographical feature, or menhir which was used as a positional marker for the sun or the moon.
31. **Four Corners:** The region surrounding the intersections of Utah, Colorado, New Mexico, and Arizona. It was the principal area where the Ancestral Puebloans lived.
32. **Great House:** A cultural, governmental, religious, food storage, and residential center for a warlord and his entourage. Great houses served a wider range of farmers who aligned themselves to a particular warlord and great house.
33. **Great Kiva:** A large circular underground structure that could hold hundreds of people. Great kivas were used for religious ceremonies.
34. **Helical rising:** The first sighting of an astronomical object in morning twilight after conjunction with the sun. When an object is in conjunction with the sun, it is viewed in the same line of sight.
35. **Hopi:** A surviving Ancestral Puebloan tribe strongly associated with the Chacoan Phenomenon and whose traditions are considered to have the greatest authenticity of the ancestral peoples because the Hopi were never conquered by the Spanish.
36. **Hovenweep Castle:** Hovenweep National Monument… A castle-like pueblo or great house that has a calendar room that faces the west.
37. **Hovenweep National Monument:** SE Utah… One of the last great Ancestral Puebloan strongholds which existed after the Chacoan Phenomenon. It was abandoned shortly before 1300 AD.
38. **Indirect sun:** Solar energy that strikes the ground at a low angle producing little in the way of heating.

39. **Insolation:** The amount of solar energy being absorbed by a body as a function of the sun angle.
40. **Hunter gathers:** A nomadic lifestyle in which groups of people gathered and hunted for their food sources.

41. **Kiva:** A round, underground structure that may have served as a religious and community center for men, as well as a place where clan members could communally live when in the canyon for religious ceremonies. Native Americans believe that they emerged from the dark underworld into the present world through a hole in the ground. The sipapu in a kiva or the kiva itself was representative of this emergence point.
42. **Masonry styles:** The specific patterns created by the stones that were used in the building walls. These patterns have allowed archaeologists to give approximate dates to pueblo rooms.
43. **Matriarchal:** A woman who rules or dominates a family, group, or state (***Merriam-Webster*** online)
44. **Mesa Verde National Park:** The most famous and frequently visited of the areas inhabited by Ancestral Puebloan people. Many Chacoans migrated northward into the Deloris River Valley of Colorado where Mesa Verde is found.
45. **Mini-Sun Dagger**: One of two dagger calendars found in Chaco Culture National Historical Park. It is located west of Gallo Campground. A natural crack in the rock allows a "dagger" of sunlight to move downward across a petroglyph panel near the time of noon around summer solstice. The dagger bisects a spiral about 10 days before and after summer solstice so it may have been used more as a predictive marker than a solstitial marker.
46. **Moon:** Used to formulate the earliest calendars… These time keepers proved difficult to intercalate with the solar year because ancient cultures were unaware of fractions.
47. **Moving observer/stationary sun:** A calendrical device which keeps the distant rising or setting position of the sun stationary through the daily change of position of an observer.
48. **Nageezi, New Mexico:** The closest town to Chaco Culture National Historical Park. It is about 30 road miles distant.
49. **Navajo:** The present indigenous population that lives in and around Chaco Culture. The Navajo began migrating southward from northern Canada (Yukon) into Chaco Culture between 900 and 1400 AD.
50. **Niche:** A corner or indentation in a wall where ceremonial objects could be kept or to which the rising/setting light of the sun could be channeled by a window, port, or doorway.
51. **Midden:** A trash mound for household refuse…
52. **Nomadic:** Moving from place to place usually for the gathering of food supplies.
53. **North Mesa:** A flat tableland bordering the north side of Chaco Culture. Pueblo Alto (new and old) is located here as well as the mini-sun dagger and ceremonial pottery shard mound.
54. **North Road:** A ceremonial roadway built from Pueblo Alto (old) towards the north to Kurtz Canyon and beyond to the San Juan River. It eventually connected to Salmon Ruin (Pueblo).
55. **Outlier:** A great house that was positioned outside of Chaco Canyon but still represented a part of the greater Chacoan world.
56. **Passive solar:** Architectural design which makes use of the sun for heating or cooling purposes.

57. **Penasco Blanco:** Spanish for "white rock point"… An early Chacoan D-shaped great house located about three miles to the west of Pueblo Bonito on Chacra Mesa. It is noted for its rocks with a white patina. It is also near the supernova pictograph, and it is one of two great houses (along with Tsin Kletsin) to be located on the mesa south of the canyon.
58. **Petroglyph:** Rock art drawings constructed from the pecking of a rock with a stone
59. **Pictograph:** Rock art made from painting with dyes
60. **Pit House:** A wood, mud-plaster dwelling partially excavated below ground level. Pit houses contain a fire pit in their centers. They may have been the forerunners of kivas.
61. **Ports (Vents):** A small opening in a Puebloan wall. Some ports were used for calendrical purposes, but most were probably employed for ventilation and daylight.
62. **Potsherds:** Broken pieces of ceremonial (painted) and common household pottery… Because Chacoan pottery styles changed with time, potsherds can be used for approximate dating purposes.
63. **Pueblo:** Spanish for "town"…
64. **Pueblo Alto:** Spanish for "high town…"A late Chacoan great house (1020-early 1100s) built on North Mesa, above Pueblo Bonito. It has a new and an old component. New Alto, Pueblo Bonito, and Tsin Kletsin are aligned north-south.
65. **Pueblo Bonito:** Spanish for "beautiful town"… The largest great house in the Chacoan world. It probably served as the ceremonial center during the Chacoan Phenomenon. Bonito was constructed between 850 AD to the early 1100s in five periods of activity.
66. **Pueblo del Arroyo:** Spanish for "town by the Arroyo…" Named because it sits next to the Chaco Wash. It is also located within several blocks of Pueblo Bonito.
67. **Puebloan Indians:** Native Americans who lived in masonry houses
68. **Puebloan Society:** The traditions, customs, religion, and aspirations which created the social order of the Puebloan culture.
69. **Red Mesa:** An region located south of Chaco Canyon, the people of the Red Mesa Valley flourished early and wilted prematurely in the Chacoan Phenomenon
70. **Right ascension:** The angular measure of an object eastward from the position of the vernal equinox to the object. Right ascension can be measured as an angle in degrees/minutes but it is more commonly denoted as a time increment in hours/minutes with the vertex of the angle placed at Earth's center.
71. **Salmon Ruins:** A late Chacoan outlier located on the San Juan River about three miles to the west of Bloomfield, NM. It was connected to the canyon by the Great North Road.
72. **San Juan Basin:** The area of NW New Mexico, about 12,000 square miles, which drains into the San Juan River. The major tributary is the Chaco River which has its sources to the north in the washes (arroyos) which cross and drain Chaco Canyon.
73. **Sipapu:** A Hopi word for the place where people emerged from an earlier underworld into this world (Gwinn Vivian, ***The Chaco Handbook***).
74. **Solstice:** Sun standstill position… The sun reaches it greatest angular distance north or south of the equator (celestial equator).
75. **South Gap:** A break in Chacra Mesa directly south of Pueblo Bonito and Pueblo del Arroyo. Roads from the south came through this area.
76. **Square Tower Ruin:** Hovenweep National Monument… A large tower-like structure built perhaps for storage or defense. It overlooked a seep which supplied a continuous source of water for the community.
77. **Stationary observer/moving sun:** A way of keeping the calendar by going to the same observing station and watching the changing position of the sun against a distant horizon.
78. **Strategic:** Necessary for fighting wars/having the capability to destroy (***Encarta***).

79. **Summer Solstice:** Summer standstill position of the sun. The location in the sky and on the ecliptic where the sun reaches its greatest angular deviation north of the celestial equator. The sun's declination is +23.5 degrees. This usually occurs on the 21st of June for the Northern Hemisphere.
80. **Sun:** Probably considered the chief god of the Ancestral Puebloans and the most important object for the creation of calendars.
81. **Sun Dagger:** Found at the summit of Fajada Butte, the three pancake-shaped rock slabs from which it was formed, channeled sunlight against a rock wall in such a way that both solstices and the equinoxes could be observed either bisecting or bracketing spirals.
82. **Sun room:** An enclosed area in which the calendar was kept.
83. **Sun watching station:** A location, often signified by a spiral or a series of concentric circles which represented a position where the sun was observed.
84. **Supernova pictograph:** The most famous astronomical pictograph of the Ancestral Puebloan world. It is found to the NW of Penasco Blanco. There are at least another half dozen representations through the Southwest.
85. **Tsin Kletsin:** The smaller of the two D-shaped great houses found south of the canyon. It represented the southern end of a north-south alignment with Pueblo Bonito and (new) Pueblo Alto.
86. **Unit house:** Hovenweep National Monument… The name of a single dwelling or small structure.
87. **Variation in the length of day:** Caused by the sun's varying declination which results in a change in the sun's rising and setting positions. This causes the sun's path length across the sky to change which varies the length of time that the sun remains above the horizon.
88. **Vigas:** Large wooden beams which supported the heavy, earthen floors of pueblo rooms. Latillas (sticks) were laid across the beams before the floors were plastered with mud.
89. **Vernal Equinox:** The position of the sun as it crosses the celestial equator from south to north. It is the location of the sun on the first day of spring.
90. **Wijiji:** A late Chacoan pueblo with solstitial alignments. Wijiji is situated about 5-1/2 miles to the east of Pueblo Bonito. Nearby are sun watching stations which were created by the Navajo.
91. **Winter Solstice:** Winter sun standstill position… The location of the sun on the ecliptic where it is at its greatest deviation south of the equator or the celestial equator. This usually occurs around the 21 of December for the Northern Hemisphere.
92. **Zuni:** A Puebloan tribe which has a strong affiliation with Chaco Culture. Zuni Indians now live in the town of Zuni about 50 miles to the south of Chaco Culture.

NOTES

CAN YOU ANSWER THE FOLLOWING QUESTIONS/STATEMENTS ABOUT ARCHAEOASTRONOMY AND THE SEASONS?

WORSHIPPING SKY OBJECTS

1. Devise a definition for archaeoastronomy using the two words, which in combination form the new word. Propose a definition which encompasses both meanings.

   a. Astronomy (to the ancients): The interpretation and understanding of the movements of the heavenly bodies.

   b. Archaeology: The study of past human life from the material remains which have been left behind.

   c. Archaeoastronomy:

2. State two reasons why early humans would have possessed an interest in the night sky.

3. Why would early humans consider the sun, moon and planets important enough to deify? Hint: What made them different from the stars?

MOTIONS OF THE "HOLY" SEVEN

4. What aspects about the moon would have made it more favorable than the sun for its use as the earliest of calendars? Hint: Consider the phase period of the moon (29.5 days) in comparison to the cycle of the year (365 days).

5. Why, in reality, did the moon turn out to be a rather poor calendar in comparison to the sun? Hint: Divide 29.5 into 365.

6. Describe several seasonal effects between summer and winter which are easily observable to anyone who cares to monitor the sun.
   a.

   b.

   c.

7. Using a foresight (a distant mountain or geographical feature) and a backsight (the position from which the observations are being conducted), identify two methods by which the progression of the seasons could be monitored. You may want to sketch your answers.

   a.

   b.

BASIC DEFINITIONS

8. The spinning of a body about its axis is a good definition for ________________.

9. The motion of a less massive body around a more massive body is termed ________________. Mass is the quantity of material a body possesses.

10. The inclination of the imaginary line about which the Earth rotates to the perpendicular of its orbital plane defines this planet's _____________________. The number of degrees measured in this angle, for the Earth, is equivalent to ________________.

11. The exact period of time it takes the Earth to complete one revolution equals _____________________, while one rotation consumes an interval of _____________________.

UNDERSTANDING THE SEASONS

12. The seasons are the result of the ________________ of the axis of the Earth.

13. The Earth's axial tilt equals ________________ degrees from the perpendicular to the ecliptic. If the axis of the Earth were perpendicular to the ecliptic, a person standing at the same location would NEVER/ALWAYS (circle one) see a change in the noontime altitude of the sun.

14. If the observer, however, is on a tilted planet, the sun's noontime altitude will appear to change. If this change is great enough, ________________ will be the result on that planet.

15. As the Earth, revolves around the sun, its axis always ________________________________.

16. Hold a flashlight at various angles to a wall, keeping the distance of the beam to the wall the same. In order to make the light fall over the smallest area, how must the beam be directed toward the wall? ____. The more obliquely the beam strikes the wall, the LARGER/SMALLER will be the area illuminated.

17. The energy source of the flashlight is the same, no matter how the beam is directed toward the wall. But the energy falling upon the wall per unit area varies, depending upon the ________________ at which the beam intersects the wall.

18. When the beam strikes the wall at a low angle there is MORE/LESS (circle one) energy per unit area. The opposite is true when the beam is at a higher angle. The same can be said for the angle at which the sun's energy strikes the Earth. This is caused by the Earth's _____________________.

THE EQUATORIAL GRID

19. The coordinate system which gives navigators the ability to locate objects on the surface of the Earth is called ________________ and ________________.

20. ________________ is like a ladder. It measures distance north and south of the equator while ________________, the long lines of Earth’s grid system gauges the distance east and west of the prime meridian. These two circles serve as reference circles that allow the establishment of Earth's grid system.

21. If the coordinate system of latitude and longitude is projected into space, a new grid system is formed which is very useful to astronomers and is called the _________________ system.

22. Where the equator intersects the sky, a new circle is formed called the ________________. Latitude circles become circles of ________________, while longitude meridians become hours of __________________.

23. Latitude must be designated north or south of the terrestrial equator. Its counterpart in the sky, mentioned in the last problem, is denoted as ________________, depending upon its location with respect to the ________________ equator.

24. Longitude is specified as east or west of the prime meridian. Its sky counterpart is measured eastward from the intersection point of the ____________________ and the ________________. This position is called the ____________________, and it represents the position of the sun at the first moment of ________________.

25. The ________________ represents the path which the sun takes in the sky as the Earth revolves around this object. Another way of defining the ________________ is to say that it is the Earth's orbital plane projected into space.

26. The number of degrees represented by the inclination of the ecliptic to the celestial equator is equal to ________________.

27. Since the sun moves along the ecliptic, it is not normally crossing the celestial equator. This means that the sun is at some angular measure above or below the celestial equator. The maximum angle which the sun can be above or below the celestial equator is equal to ________________. This corresponds to a declination of _________________ or ________________ respectively.

28. The maximum deviation of the sun above or below the celestial equator occurs on the dates of ________________ and ________________ respectively, and are known as the ____________________ and the ____________________ respectively.

29. The midsummer sun is simply another word for the _____________________ while the midwinter sun represents the _____________________ sun.

30. The total deviation of the sun, from its highest position in the sky at noon (73.5° for Allentown) to it lowest position in the sky at noon (26.5° for Allentown) is equal to ________________. How is this number related to the inclination of the Earth's axis from the perpendicular to the ecliptic?
____

31. If the axis of the Earth was inclined 35° from the perpendicular to the ecliptic, the total deviation of the sun from its highest to its lowest position would be __________________ degrees.

32. The inclination of the Earth's axis is responsible for what phenomenon which was very keenly watched by the ancients?

33. What significance does 23 ½° have to the Earth's grid system of latitude measurement?

    a. Tropic of Cancer/Capricorn:

    b. Arctic/Antarctic Circle:

34. At the time of the vernal and autumnal equinoxes the sun rises in the direction of due ________________ and sets due ________________. The declination of the sun at these two times of the year is the same and equals ________________.

35. If the sun or any other celestial object is at a positive (northerly) declination, its rising position will always be ________________ of east, while its setting location will always be ________________ of west.

36. Objects with negative declinations will always rise and set to the ________________ of east and west respectively.

37. The celestial equator lies along the declination circle of ________________.

STONEHENGE

38. Where is the location of Stonehenge? State a country and the distance and direction from its principal city.

39. The construction of Stonehenge occurred in ________________ stages. To the nearest 1000 years, the first stage was begun around ________________ while the last stage was completed about ________________.

40. ________________ The massive upright boulders which form the outer circle and inner horseshoe structure of Stonehenge...

41. ________________ The rock cap stones which lie on top of the upright boulders...

42. ________________ The freestanding structures which compose the center horseshoe. They consist of two uprights and a lintel cap stone.

43. ________________ The sun rises over this sarsen at midsummer. The declination of the sun at this time is ________________.

44. ________________ Fifty-six holes were equally spaced in a circle surrounding the outer stone circle of Stonehenge I.

45. ________________ A circular trench, about 310 feet in diameter, with the detritus thrown toward the inside of the circle.

46. ________________ The corridor which lead away from the monument in the direction of midsummer sunrise and eventually joined with the Avon River.

47. ____________________ The sun set behind this structure at midwinter when viewed from the center of Stonehenge.

48. ____________________ Sunrise at midwinter was observed to occur at this location.

49. Based upon the aforementioned alignments, Stonehenge could be described as a structure responsible for what practical function.

NOTES

ANSWERS TO SESSION THREE QUESTIONS

WORSHIPPING SKY OBJECTS

1. Archaeoastronomy: The use of astronomy by the ancients to monitor the positions of heavenly bodies for practical purposes (establishing a calendar, predicting eclipses).
2. formation of a calendar to monitor a) agricultural activities, b) religious ceremonies, c) governmental activities
3. They were a) bright, b) changed positions in the sky, and c) the sun was responsible for life.

MOTIONS OF THE "HOLY" SEVEN

4. The moon went through a series of phases in a shorter period of time (one month) than the cycle of the sun (one year). A shorter lunar phase period was easier to observe.
5. The phase period of the moon (29.5 days) did not result in a whole number when divided into the year (365.24 days). Fractions were meaningless to ancient cultures. If a planting occurred at the time of the full moon on the last day in April, would farmers be sowing their seeds at the same time next year? No! The phase of the moon and the seasonal dates did not mesh consistently.
6. a) duration of daylight changes, b) rising and setting positions of the sun change, c) altitude of sun above horizon changes
7. a) stationary observer monitors a moving sun, b) moving observer keeps the sun rising at the same location by changing his/her position

BASIC DEFINITIONS

8. rotation
9. revolution
10. axial tilt, 23 ½
11. 365.24 days, 23 hours 56 minutes

UNDERSTANDING THE SEASONS

12. inclination
13. 23 ½, NEVER
14. seasons
15. points in the same direction
16. The flashlight beam must be perpendicular to the wall, LARGER
17. angle
18. LESS, axial tilt

THE EQUATORIAL GRID

19. latitude, longitude
20. latitude, longitude
21. equatorial coordinate
22. celestial equator, declination, right ascension
23. + or -, celestial
24. celestial equator, ecliptic, vernal equinox, spring
25. ecliptic, ecliptic
26. 23 ½°
27. 23 ½°, +23 ½°, -23 ½°

28. June 21st, December 21st, summer solstice, winter solstice
29. summer solstice, winter solstice
30. 47°, It is twice the angular amount of the Earth's axial inclination.
31. 70
32. the seasons
33. a) Tropic of Cancer = 23 ½° N. lat., Tropic of Capricorn = 23 ½° S. lat. Tropic of Cancer/Capricorn are 23 ½° from the equator. b) Arctic Circle = 66 ½° N. lat., Antarctic Circle = 66 ½° S. lat. Arctic/Antarctic circles are 23 ½° from their respective terrestrial poles.
34. east, west, 0°
35. north, north
36. south
37. 0°

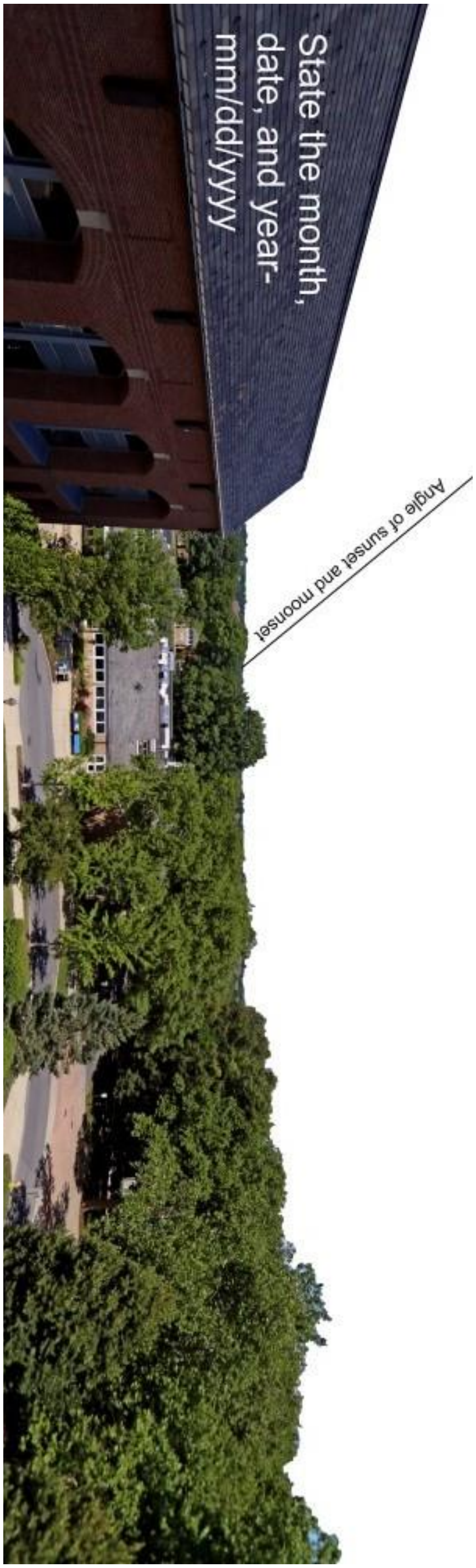
STONEHENGE

38. England, about 90 miles to the west of London
39. three, 3000 BC, 2000 BC
40. sarsens
41. lintels
42. trilithons
43. heel stone, +23 ½°
44. Aubrey holes
45. ditch and bank
46. avenue
47. great fallen trilithon in the southwest
48. great standing trilithon in the southeast
49. a) monitoring the season, b) establishing a calendar

NOTES

NOTES

SUNDOWN/MOONSET



Name ____

Instructions: In this exercise note the setting position of the sun against the western horizon of the Moravian University campus and the City of Bethlehem as viewed from Collier Hall's rooftop observatory. You need not draw an actual disk for the sun. Simply mark the setting position with an arrow pointing to the appropriate location. Indicate the date in which the observation was made above the arrow and in the table below this paragraph. This exercise will be repeated several times.

CAUTION: NEVER STARE DIRECTLY AT THE SUN!

Date _______________, Sunset Time ____________

Date _______________, Sunset Time ____________

Date _______________, Sunset Time ____________

Date _______________, Sunset Time ____________

Date _______________, Sunset Time ____________

If you were able to observe the sun with the proper filtration, what was your reaction upon first seeing the solar disk?

Comment on any changes that you have witnessed with regards to the sun's setting position during the past several weeks.

MOONRISE/SUNRISE

Name ____________________________________

Instructions: In this exercise please note the rising position of the moon against the eastern horizon of the Moravian University campus and the City of Bethlehem as viewed from Collier Hall's rooftop observatory. Do not draw an actual disk for the moon. Simply mark the rising position with an arrow pointing to the appropriate location. Indicate the date in which the observation was made above the arrow and in the correct location below.

This exercise will be repeated several times.

Date ____________, Moonrise Time __________

Date ____________, Moonrise Time __________

Date ____________, Moonrise Time __________

Date ____________, Moonrise Time __________

Date ____________, Moonrise Time __________

If you got a chance to view the moon through a telescope, what was your first impression when you looked through the eyepiece and obtained a good focus?

Comment on changes, if any, that you have observed regarding the moon's rising position during the past several nights.