ASTR 2000 HW#5 DUE FEBRUARY 24th NAME:______KEY:________

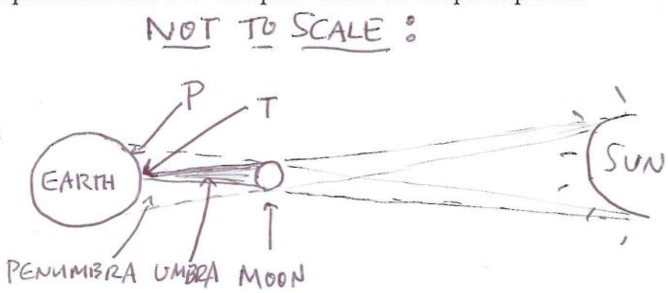
1. Solar eclipses are one of the most awesome of human experiences.

A. In the space below draw the geometry of an eclipse of the Sun (i.e., the relationship between the Sun, Moon and Earth as viewed from well away from the Earth), labeling each object in your drawing, and including the darkest (umbra) and less dark (penumbra) parts of the shadow. Place a "T" at a typical place where the eclipse is total and a "P" at a place where the eclipse is partial.

3 points; 1 for correct order:
Sun/Moon/Earth

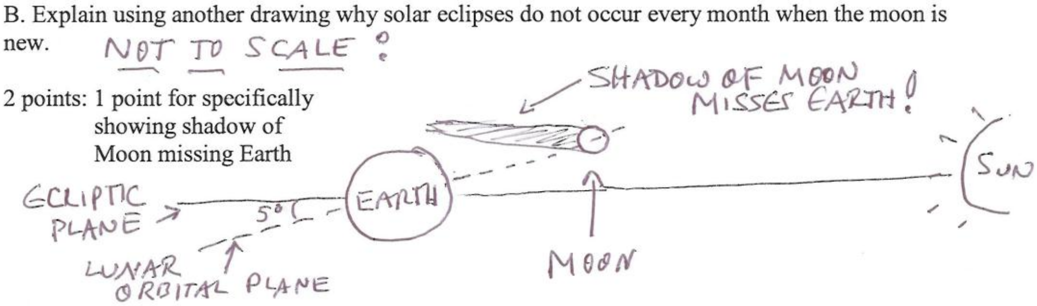
1 for location of penumbra & umbra

1 for location of total & Partial eclipse of Sun



B. Explain using another drawing why solar eclipses do not occur every month when the moon is new.

2 points: 1 point for specifically showing shadow of Moon missing Earth



C. Now please look at Table 4 on the next page which lists all the eclipses (i.e., both lunar and solar; both total and partial) which occurred in the 1980s. Notice the third column, which tabulates the number of days from the listed eclipse until the next eclipse.

(1). Notice that the same numbers occur again and again. Note specifically, that almost every year (excepting 1980 & 1984), a lunar or solar eclipse is followed by the other type of eclipse just 14-16 days later. Explain why this occurs so frequently, especially considering the "regression (i.e., backwards = east-to-west movement) of the lunar "nodes."

14—16 days is the difference between full and new moon times or vice versa. So a solar eclipse is often followed by a lunar eclipse or vice versa. This is because the nodes of the lunar orbit move hardly at all in this amount of time [taking 18 2/3 years to move once around; i.e. in 15 days the lunar node moves 0.8 degrees only away from its point crossing the ecliptic; so this OFTEN happens!]

(2). The other numbers which recur frequently in column 3 of Table 4 corresponds to intervals of 5, 5 1/2 or 6 moons. Explain why these intervals recur, again using your knowledge of the lunar nodes. Make sure your answer includes why these intervals aren't exactly centered on one half year exactly (i.e., why intervals are not at 5 1/2, 6 and 6 1/2 moons?).

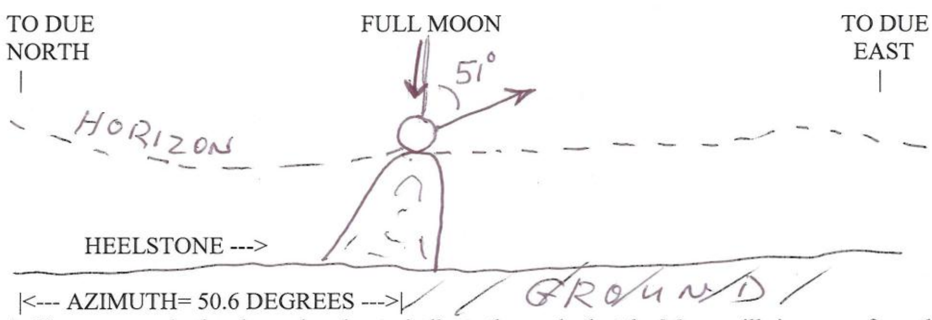
The other numbers are the nearest whole division of the lunar cycle (or half-division for a lunar eclipse followed by a solar eclipse or vice versa) closest to the next node crossing of the ecliptic. This defines the amount of time between two "**eclipse seasons**". These eclipse seasons are centered two weeks short of one-half year because the nodes move backwards [east-to-west through the stars] and so meet the Sun before it moves a full180 degrees, one half year.[performing the division like in part (1) above, the nodes move 9 degrees backwards in ½ year and so the eclipse seasons move ~ 9 days backwards through the calendar in ½ year or ~18 days in a full year].

(3). Shown below is a portion of the number "glyphs" (word pictures) on page #53 of the Dresden Codex, one of the 4 remaining Mayan books which is named after the European city in which it was "rediscovered". Given the numbers you see in this Table at right, what do you think the Maya were doing? Explain in your answer how sound you think this reasoning is and why.

They were recording or predicting [I believe the latter] eclipses since these are many of the very same numbers as in Table 4. This reasoning appears quite sound since 148, 177 & 178 are not very common numbers to be used so frequently.

2. At the Mid-Winter Full Moon (that full moon closest to the Winter Solstice, but not exactly on Dec 21st), an archaeo-astronomer visiting Stonehenge (latitude 51 degrees north) notices the precise alignment of the Full Moon and the Heelstone as shown below:

*** VIEW IS TO THE NORTH-EAST COVERING 90 DEGREES NORTH THROUGH EAST



A. Use an arrow in the above drawing to indicate the angle that the Moon will rise away from the Heelstone. How much is amount of that angle as measured down from the vertical? Explain.

Latitude = 51 degrees ➔ therefore the angle of rising of all objects, including Sun, Moon, stars and planets is 51 degrees down from the vertical [90 – 51 = 39 degrees up from horizontal].

B. This particular Full Moon is located right on the ecliptic plane (it is rising exactly over the heelstone after all!). What is the ecliptic plane? Describe where the Sun will rise the next morning on the sketch above?

The ecliptic is the plane of our Solar system, near which all moving objects (Sun, Moon, planets) appear in the sky [the ecliptic takes a path through the zodiac constellations]. Specifically the ecliptic is the exact path taken by the Sun through the zodiac; other objects, Moon & planets, take paths close to but not precisely the same as the Sun does. It will rise south of east

C. Is the Mid-Winter Full Moon always on the ecliptic plane? If not, how often is the Mid-Winter Full Moon exactly on the ecliptic plane? Explain

No, the Moon swings above and below the ecliptic due to its 5 degree tilt relative to the ecliptic, swinging back and forth on either side of the ecliptic over the period that the nodes move once around the lunar orbit; i.e., the Moon's location swings through the ecliptic **twice** in any one nodal period (18—19 years). And so the solstice Full Moon will rise on the ecliptic **twice in any 19 year period.** [That is, the Moon takes each standstill position, major and minor, once every 19 years, and (just like there are two equinoxes and one summer and one winter solstice in any one year) the ecliptic crossing happens twice in any 19 year period. Because the nodes move once around in 18.6 years, this means that the Major Standstill alternates between winter (furthest north Full Moon) and summer (furthest south Full Moon).]

The solstice full moons (summer and winter) will rise twice on the ecliptic in a 19 year period. However, the winter solstice moon will rise only once in the 19 year period

D. What astronomical event occurs when the Mid-Winter Full Moon is on or quite close (< 1/2 degree) to the ecliptic plane? Explain

A lunar eclipse. Because it is a Full Moon on the ecliptic it is an eclipse season; i.e. the Moon is in one of the two nodes. [The ½ degree comes from the angular size of the Sun and Moon in the sky = ½ degree].

3. We have seen from examples in class that ancient civilizations that were settled in cities and had hierarchical "class" social structures also had experts who knew very detailed information about the sky (e.g., Egyptian, Babylonian, Ancestral Pueblos, Maya, Inca). For these cultures we see plenty of physical evidence in either written knowledge (e.g., Babylonian cuneiform tablets, Maya codices, etc) or in building or monument orientations or "light shows" (e.g., The Chaco Sundagger, Stonehenge, the Giza Pyramid alignments, the Newgrange passage tomb, the Mortuary Temple of the Pharaoh Amenhotep III at Thebes, etc etc) of this astronomy.
Other cultures were more nomadic (e.g. Lakota, Navajo, Aboriginal Australian, people of Nabta Playa) or left no written records of their knowledge (e.g., Inca) and/or no buildings (e.g., Chumash, Australian Aboriginals) showing explicitly their astronomical knowledge. We might know very little of what they knew about the sky except for the remaining knowledge of tribal elders that comes down to us in the present day through a strong oral tradition.

**** This question was NOT GRADED;

. Here I describe some of the points you **could** consider in answering this question, which was meant to be open-ended to get you to reflect creatively on what you have learned so far. ****

a). Make up a fictional ancient culture of your own devising describing them in terms of where on the Earth they lived and which of the above two types of cultural categories they fit into. Describe this culture briefly including characteristics you think might bear on their astronomy.
b). For this fictional culture describe a likely calendar that they might use. How would they set and re-set their calendar. Is their calendar: Solar, Lunar or Luni-solar and why?
c). For this fictional culture describe their likely relationship with the Sun and Moon; which of these two heavenly bodies is more important in their cosmology and why?

[In addressing this question, I thought of the following framework that helped me think about it. In my mind this framework revolved around two simple ideas: geography and social organization. But you may have had other ideas, which are also correct.

Geography: Does the culture live in the Tropics or not?

Organization: Is the culture NOMADIC (i.e., relatively egalitarian, with mostly equal tasks, and so lacking the few specialists who have time to study the heavens for the culture) or **CITY DWELLERS** (i.e., more likely to be hierarchical with specialists for astronomy)? [The division by social organization is obviously a simplification and arguable….but it is a place to start!]

1. **Geography:**

a. Solar calendars and cosmologies are de-emphasized in the Tropics because the Sun changes location and time above horizon very little during the year. On the other hand Solar calendars and cosmologies are very prevalent at mid-latitudes where the seasonal swings of the Sun are far more obvious and more critical to life.

b. Lunar calendars and cosmologies take on relatively more importance in the Tropics given de-emphasis of the Sun in importance.

c. The Cosmic Whirlpool of the North (or South) Celestial pole is more important the further you go away from the Equator and it establishes an **axis mundi** using the cardinal directions. Closer to the equator the axis mundi would be linked to other natural phenomena, like the solar zenith passages days (e.g., the Inca even marked nadir (opposite of zenith) passage days!).

2. **Social Organization:**

a. Nomadic cultures had little need for extremely accurate calendars or complex cosmologies so that, like the Lakota, the use of heliacal rising stars to set a seasonal or sacred calendar is more likely. A sedentary culture would be more likely to have a more detailed Solar or Luni-Solar calendar using fixed markings, either natural (horizon) or human-made (building alignments; circles of stones; meridian lines using a gnomon; etc).

b. City Dwellers are more likely to have complex societies where individuals had specific jobs, one of which could have been astronomer. And since the status (and life) of this individual could well be affected by the knowledge he/she had and shared with other individuals in power, the astronomy of city dwellers could be more complex; i.e., more complex calendars even utilizing auguries or astrology. Accurate calendars also support commerce and other complex social functions. Other detailed knowledge (e.g., ability to predict eclipses using the detailed study of the motion of the Sun [solstice and equinox markers]) and Moon [major and minor standstill markers]) would be more important in more complex social organizations.