ASTR 2000 HOMEWORK #3 DUE THURS Feb 20th   NAME: ________KEY______

1. (11 POINTS) SETTING AN ACCURATE CALENDAR USING OBSERVATIONS OF THE SUN

A. (3 points) Many ancient peoples created and maintained a calendar based upon the Sun (and thus the seasons). In order to maintain the accuracy of a solar calendar, specific **OBSERVATIONS** of the Sun were made. Different ancient cultures used different methods largely due to their different geographical locations on the Earth (either local topography or terrestrial latitude, or both). By considering various ways in which this was done, list three (3) **DIFFERENT METHODS for OBSERVING** the Sun to set the calendar.

1. rising or setting locations of Sun on horizon

2. length or location of Sun's shadow or pin hole image of Sun along a meridian line

3. heliacal rising of stars (very first appearance of stars seen just above the Sun at dawn)

4. in the tropics, zenith passage days

5. in the arctic, first appearance of the Sun above horizon

B. (5 points) Choose **one of the methods you listed above** and pick an ancient culture which used this method to set its calendar or time its ceremonies. In the space provided below, write a paragraph describing how this method was used by this culture for this purpose and why the geographical location of this culture made this the best method. **BE AS SPECIFIC AS POSSIBLE IN YOUR DESCRIPTION.**

Example of a good paragraph: (elaborations between brackets [] not required)

The Hopis method #1. the Sun Priest at Walpi on First Mesa sat in a specific chair on the roof of his house, which provides a precise backsight location for observations of the Sunset over the San Francisco Mountains to the southwest (the foresight is the mountains). The calendar is obtained through watching the Sun set over specific spots; [e.g., 11 days before Soyal (Winter Solstice) the Sun sets in a sharp "notch" in this mountain range].

OR

That Maya who live in the tropics used "zenith tubes" to observe the two days per year that the Sun goes directly through the zenith. The table below give the actual "zenith passage days" which could be observed from the top of the tube sighting the image of the Sun reflected in a flat stone basin of water at the bottom of the tube. When the Sun's reflected image is NOT visible because it is blocked by the observer's [called a "day Keeper" in Maya] head, that is the zenith passage day. [These observations could be used to reset the "Haab" solar calendar.

C. (3 points) Very early (circa 2000 B.C.E.) in Babylonia and Egypt, calendars were kept which used BOTH the Sun (and thus the seasons) AND the phases of the moon. For such a calendar to "work", each new year would have to begin at the same lunar phase. Explain why this doesn't work in the long-term and determine how quickly (be quantitative) a lunar calendar would get "out of step" relative to a solar calendar. {If you wish you can answer by giving the number of days that would have to be inserted into or deleted from a lunar calendar to keep it in step with a solar calendar}.

Helpful numbers: length of Tropical year: 365 ¼ days
Length of lunar synodic period (cycle of phases): 29 ½ days

29.5 x 12 = 354 days for 12 complete lunar cycles.

365.25 – 354 = 11 days short. To stay on a lunar calendar, this method "loses" 11 days each year, or a little more than one month every 3 years. To keep a semi-accurate luni-solar calendar would require adding a full month every 2—3 years. [This is done in the sacred Jewish calendar which adds an extra month (second month of Adar) using a prescription that covers any one 19 year period. Specifically the "leap years" in which a 13^{th} month is added to the Jewish year are in the 3^{rd}, 6^{th}, 8^{th}, 11^{th}, 14^{th}, 17^{th} and 19^{th} years in any one cycle of 19 years.]

2. (9 Points; 3 points for each part) The tropics on the Earth are the latitudes where the Sun can be seen to cross exactly through the zenith on at least one day of the year.

a). What are the latitudes of the tropics and what has this to do with the tilt of the Earth's pole in space relative to the ecliptic?

23 ½ degrees north to 23 ½ degrees south, which is the tilt of the Earth's polar axis in space relative to the ecliptic plane. [These latitudes are termed the "Tropic of Cancer" in the north and the "Tropic of Capricorn" in the south]

b). Hawaii is the only American state in the tropics since it is at 20 degrees North latitude. The *chart on the next page* shows the "zenith passage" days for locations at different latitudes. Explain what is meant be a "zenith passage" day and use this chart to determine for how long the Sun stays north of the zenith at noon as seen from Hawaii.

A zenith passage day is a day when the Sun crosses the meridian exactly at the zenith. In the tropics this happens twice per year (except at exactly 23 ½ degrees North and South).

In Hawaii at 20 degrees north, the Table of Zenith passage dates shows that the Sun stays "north of the island", i.e. goes across the meridian north of the zenith on 64 consecutive days.

c). The "classic" Maya civilization flourished from 500-1000 AD and lived at 15 degrees north latitude in parts of southern Mexico and northern Central America. The Maya used precisely vertical tubes of stone to observe quite accurately the zenith passage days for the purpose of setting their Solar calendar (called the "Haab"). Why can't we use this method to set our calendars here in Boulder?

Here in Boulder, well north of the tropics the Sun **never** goes through the zenith and so is never exactly vertical.

ZENITH PASSAGE DATES OF THE SUN FOR OBSERVERS AT DIFFERENT LATITUDES

LATITUDE	DATE(S)	NUMBER OF DAYS SUN IS: NORTH/SOUTH OF ZENITH
23.5 North	June 22	1/ 364
20 North	May 21, July 24	64/ 301
15 North	May 1, Aug 12	103/ 262
10 North	Apr 16, Aug 28	134/ 231
5 North	Apr 3, Sep 10	160/ 205
Equator	Mar 21, Sep 21	184/ 181
5 South	Mar 8, Oct 6	212/ 153
10 South	Feb 23, Oct 20	239/ 126
15 South	Feb 8, Nov 3	268/ 97
20 South	Jan 21, Nov 22	305/ 60
23.5 South	Dec 21	364/ 1

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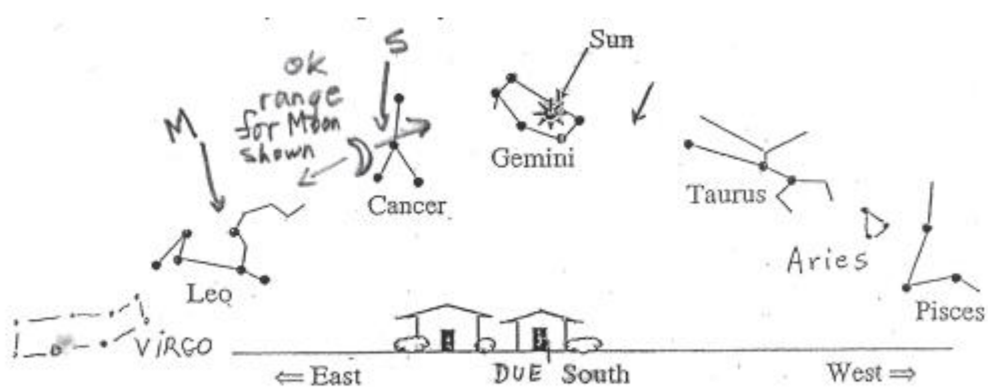
3. (10 points; 2 points for each part) If you could see stars during the daytime, this is what the sky would look like on a certain day looking due south from Boulder. The Sun is "in" the stars of the constellation of Gemini at noon. For the purpose of this homework assume that each zodiac constellation is ***exactly 30º*** *along the ecliptic.*



a). The location of the Summer Solstice Sun is marked with an arrow. What is the **approximate date** (day and month, not year) of the depiction above? Explain.

The difference is about half a zodiac constellation or half of one month (30 days). Thus, 15 days **after** the solstice ➔ June 21st + 15 days = June 31st + 5 days = **July 5th**.

b). At what time of year would the stars of Gemini be visible crossing the local meridian **at midnight**? Explain.

Six months later (one half turn of the Earth as it moves around the Sun) or **early January**

c). On the day depicted above, it is the night of a waxing crescent Moon. Locate the approximate position of the crescent Moon on the sketch above part (a) above, sketch the appearance of the waxing crescent *at that location* and describe when this Moon would be visible in the sky and where relative to the eastern or western horizon at sunset.

See chart on last page.

This Moon would be visible above the western horizon at sunset.

d). One month later it is again a waxing crescent Moon. Using arrows labeled *S for Sun* and **M for Moon**, locate the Sun and Moon on the sketch above part (a) above.

See chart on previous page

e). Has the Moon moved more than, less than or exactly 360^{o} relative to the stars between the time specified in part (c) and the time specified in part (d) ? Explain.

More than 360 degrees since it was in Cancer previously and now, one month later, it is in Leo. So it has moved **more than 360^{o}**.