

POINTS FOR EACH PART ENCIRCLED

1. (12 points) The precession of the equinoxes might be described as the "slowest hand" on the cosmic clock of the ancients, taking approximately 26,000 years to cycle once around.

a). (2 points) Explain why it is called the "precession of the equinoxes"? What has this motion to do with the equinoxes?

(2) The "wobble" of the Earth's pole causes the stars which rise with Sun on equinox down to slowly shift; i.e. these stars "precess" w.r.t. The Sun

b). (2 points) Since "once around" is 360 degrees. How long does it take the precession to move the location of the Sun by just one degree relative to the stars? By one full zodiac constellation (assume that all zodiac constellations are exactly 30 degrees along the ecliptic)? Show your work!

(1) $26000 \text{ years per cycle} \div 360 \text{ degrees per cycle} = 72 \text{ years per degree}$

(1) $72 \text{ years per degree} \times 30 \text{ degrees constellation} = 2167 \text{ years per constellation}$

c). (3 points) Assuming that the Spring Equinox Sun is located at the very first degree (western-most edge) of the constellation of Pisces at the year 2000 CE, where is the Summer Solstice Sun in the year 2000 CE? The Fall Equinox Sun? The Winter Solstice Sun? (Find names of zodiac constellations and their order on the next page of this homework).

- (1) Summer solstice - westernmost point (1st degree) of Gemini
 - (1) Fall equinox - " of Virgo
 - (1) Winter Solstice - " of Sagittarius
- [can read off Table 1 column #3]

d). (3 points) Same question as part (c). except change the date to 0 CE. Claudius Ptolemy codified Babylonian/Greek astrology in approximately 200 CE.

- [Spring Equinox - Aries] Summer Solstice - Cancer (1)
 - (1) Fall Equinox - Libra Winter Solstice - Capricorn (1)
- [CAN READ OFF TABLE 1 COLUMN # 4]

Table 1 lists the 12 constellations in the Babylonian zodiac used today along with the month during which the Sun is in the direction of these stars today (column 3) and 2000 years ago (column 4). Because Table 1 may confuse many of you who are familiar with astrology or at least with your birth *Sun sign*, column #4 is labeled as the "Astrological Month", the dates when the Sun is "in" the astrological sign corresponding to the constellation of stars. The dates in columns 3 & 4 differ due to the *precession of the equinoxes*.

Table 1: The Babylonian/Greek Zodiac

Constellation Name	Depiction	Sun in Constellation	Astrological Month	Visible in Early Evening
SUN's location :		TODAY (2000 CE)	in 0 CE	
Pisces	Two Fishes	21 Mar – 20 Apr	21 Feb – 20 Mar	Fall
Aries	Ram	21 Apr – 20 May	21 Mar – 20 Apr	Fall/Winter
Taurus	Bull	21 May – 20 June	21 Apr – 20 May	Winter
Gemini	Twins	21 June – July 20	21 May – 20 June	Winter
Cancer	Crab	21 July – 20 Aug	21 June – 20 July	Winter/Spring
→ Leo	Lion	21 Aug – 20 Sept	21 July – 20 Aug	Spring
Virgo	Maiden	21 Sept – 20 Oct	21 Aug – 20 Sept	Spring
Libra	Scales	21 Oct – 20 Nov	21 Sept – 20 Oct	Summer
Scorpio	Scorpion	21 Nov – 20 Dec	21 Oct – 20 Nov	Summer
Sagittarius	Centaur	21 Dec – 20 Jan	21 Nov – 20 Dec	Summer
Capricorn	Sea Goat	21 Jan – 20 Feb	21 Dec – 20 Jan	Summer/Fall
Aquarius	Water Bearer	21 Feb – 20 Mar	21 Jan – 20 Feb	Fall

e). (2 points) Even the approximate date of the ancient text called the Brahmin Sutras is a topic of debate since there is no recorded date for this ancient text. However, the Sutras mention that when they were written, the Summer Solstice Sun was in the "Nakshastra" that includes the bright star Regulus (The Nakshastras are the 28 "lunar mansions"; similar to zodiac constellations but one for each day of the lunar sidereal period). Regulus is at the very western-most edge of the zodiac constellation of Leo. Using the rate of the "clock" of precession that you calculated in part (b) above, and the location of the Summer Solstice Sun you found in parts (c) and (d), estimate the approximate date for the writing of the Brahmin Sutras.

one constellation or ≈ 2000 years earlier than when summer solstice sun was in Cancer (which was ≈ 0 C.E. from part (d))

⇒ Sutras written \approx 2000 BCE. (2)

2. (10 points) Here are various TIME INTERVALS from our studies this term (e.g., the time interval for the Earth to go around the Sun is 1 year; the time interval for a complete cycle of lunar phases is 29.5 days). Provide values for these time intervals as accurately as you can.

1 POINT EACH

- a). The approximate length of time for the "Age of Gemini" (also known as the "Golden Age").
2167 or 2000 years
- b). The typical length of time of a total eclipse of the Sun as seen from any one location here on Earth.
3-8 MINUTES
- c). One cycle of the Tzolkin sacred calendar.
260 days
- d). The time period for the Moon to move through all 12 Zodiac constellations (its sidereal period).
27 1/3 days (28 days or)
- e). The time period between consecutive "Minor Standstills" of the Moon.
18 1/2 years
- f). The length of time between consecutive Venus heliacal risings as seen from the Caracol at Chichen Itza.
584 days
- g). The "Great Year" of precession, the time for one full "wobble" of the Earth's polar axis in space.
26000 years
- h). The full Maya Long Count.
1,872,000 days or \approx 5125 years
- i). One cycle of the Maya Calendar Round (Tzolkin + Haab).
52 years
- j). The length of time between two consecutive heliacal risings of the Pleiades as seen from the Coriacañcha in downtown Cuzco, Peru.
1 year

3. (8 points) The Big Horn Medicine Wheel is a circle of rocks and "spokes" of rocks that form a wheel-like structure (see picture on next page). Archaeologists believe that this structure was built by ancestors of present-day Lakota Native Americans and that the spokes point towards the rising or setting locations of bright stars on the horizon (see plot of these alignments below the picture on the next page). However, due to the "precession of the equinoxes", these alignments are only accurate for a limited range of dates in the past (horizontal bars show the range of dates when the alignment of the medicine wheel is accurate for each star). Using the dates for which ALL of the alignments are accurate, it is estimated that the date of construction of the Medicine Wheel was between 100 and 300 CE (shaded region in the plot). This date agrees with radioactive Carbon dating of charcoal remains in the central cairn (fire pit).

a). (2 points) Explain why the precession alters the rising and setting points of fixed stars like Aldebaren over many hundreds or thousands of years.

precession shifts the North Celestial Pole relative to the stars \Rightarrow stellar positions shift relative to the celestial coordinates (stars have different celestial latitudes and longitudes) and so different rising and setting locations at any one place on Earth.

b). (2 points) Explain why the precession does NOT alter the rising and setting points of the Sun at specific time of year (e.g., summer solstice).

Wobble is around the pole of the ecliptic plane so that the angle between the Earth's pole & ecliptic remains fixed at $23\frac{1}{2}^\circ \Rightarrow$ Sun's location remains fixed

c). (2 points) These same Lakota make a pilgrimage migration each year to Bear Lodge Butte (Devil's Tower) to conduct their sacred "Sun Dance" ceremony when the Sun enters the Bear Lodge constellation (Gemini). Today (c. 2000 CE) the Sun reaches Gemini in late July by our calendar. What time of year did the Sun reach the Bear Lodge constellation in 200 CE?

late June, near summer solstice [appropriately]

d). (2 points) Explain why this timing supports an historical date for the Sun Dance ceremony similar to the estimated construction date for the Medicine Wheel (i.e., circa 200 CE)?

Sun Dance is solstice ceremony. In 200 CE Sun reaches Bear Lodge constellation (Gemini) at summer solstice. Medicine wheel gives similar date

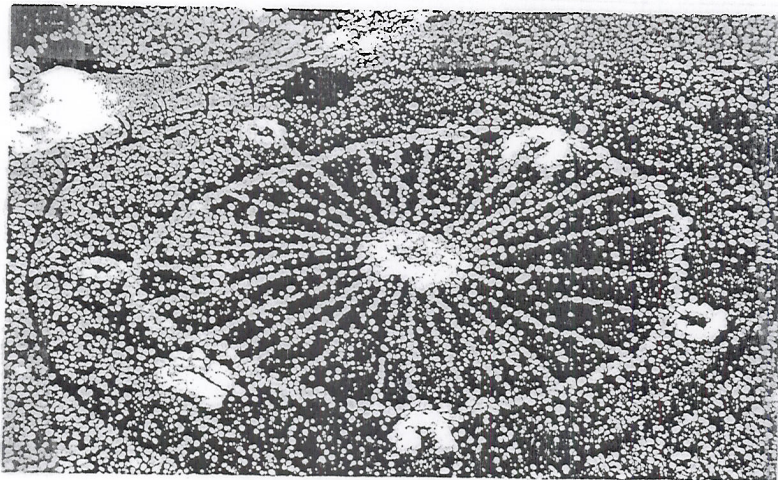
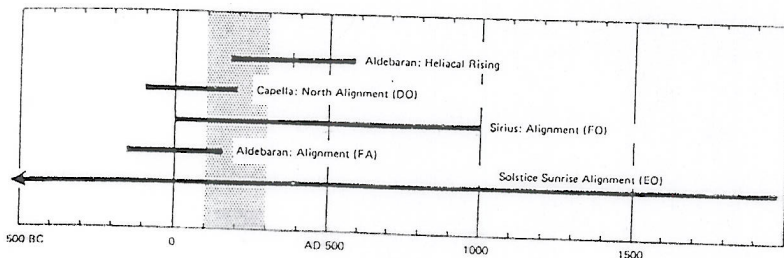


Figure 3
The Bighorn medicine wheel, in Bighorn National Forest, west of Sheridan, Wyoming. The diameter of the wheel is about 90 feet, that of the central hub about 12 feet. Twenty-eight spokes radiate outward from the central hub, and six cairns of stone mark the wheel's periphery. (U.S. Forest Service photograph)



\Rightarrow Lakota Sun Dance ceremony is at least 2000 years old! [held every year!]