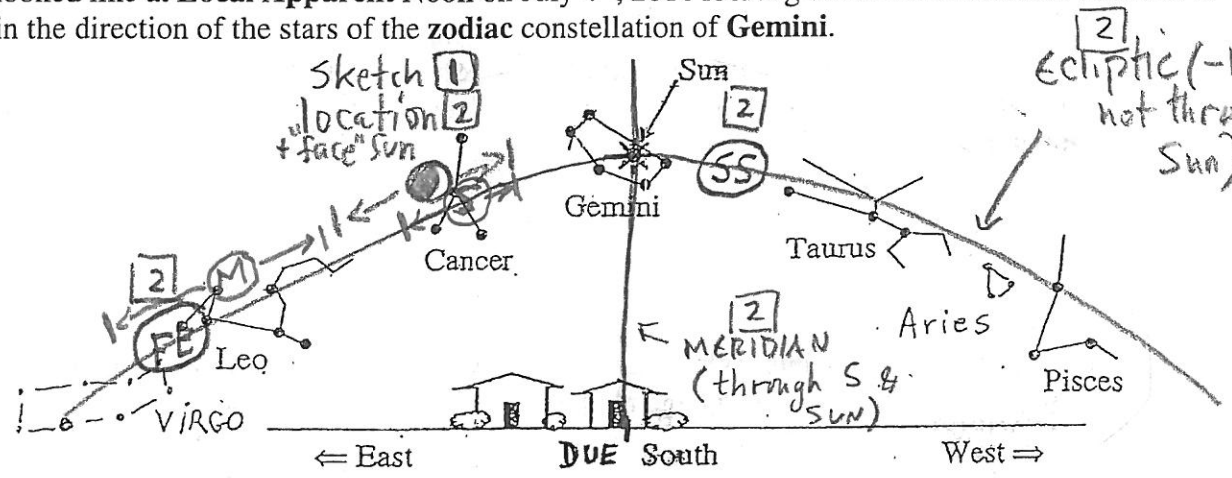
MIDTERM EXAMINATION: ASTR 2000 October 11th, 2016

NAME: KEY SEAT #: _____

100 POINTS AND 4 QUESTIONS TOTAL: POINTS FOR EACH QUESTION IN PARENTHESES
ONE PAGE OF NOTES AND A CALCULATOR ALLOWED. THINK more than you write!

POINTS IN SQUARE BOXES

1. **SUN & MOON** (25 points) If you could see stars during the daytime, this is what the sky looked like at **Local Apparent Noon** on July 4th, 2016 looking south from **Boulder**. The Sun is in the direction of the stars of the **zodiac** constellation of **Gemini**.



a). (8 points) On the sketch above draw in and label the locations of the **ecliptic** and the **meridian** and explain their significance for the location and motion of objects in the sky .

[2] ecliptic - the plane of the Solar System in the sky defined by the apparent orbit of the Sun. Sun, Moon & Planets all found on or close to the ecliptic

[2] meridian - local N-S line in the sky; goes through the meridian The daily motion of all objects in the sky culminate (reach their highest altitude) when they cross the meridian

b). (4 points) Mark the approximate locations of the Sun on the days of the **Summer Solstice** (label the correct location with an **"SS"**) and the **Fall Equinox** (label with an **"FE"**). {On those specific days, but **not necessarily** at noon on those days}

c). (5 points) The noontime sky sketched above is on the day of a **Waxing Crescent Moon**. Locate the approximate position of the **Waxing Crescent Moon** on the chart with a **drawing** of the appearance of this moon phase in the sky, shading the darker portion. What time of day or night was this moon phase most easily seen and where was it seen relative to the sunset or sunrise point on the horizon?

[1] most easily seen just after sunset in the west near sunset location

ON "OTHER SIDE" OF PAGE

d). (4 points) Using your sketch of the Waxing Crescent Moon (you can repeat it in the space below if you wish) explain the difference between the **"dark side"** and the **"back side"** of the Moon. {question courtesy of Pink Floyd}

[2] backside - physical side of Moon we never see from ⊕; always faces away from us. Sometimes in darkness, sometimes in light

[2] dark side - night-time hemisphere on Moon. Changing % of dark side on front side of Moon creates phases.

e). (4 points) Exactly one **synodic period** of the Moon later than July 4th, 2016 locate the position of the Sun on the sketch above with an **"S"** and the Moon with a capital **"M". What is the moon phase on this new date?**

[2] [1] locations

[1] waxing crescent Moon

2. **CALENDARS** (22 Points) While our modern civil calendar, the **Gregorian Calendar,** is a pure Solar calendar, many ancient and modern indigenous calendars are either purely *lunar* or "*luni-solar*".

a). (5 points) The ancient calendar in the eastern Mediterranean (Greek and Babylonian) was a *"luni-solar"* calendar. Describe a *luni-solar* calendar explaining the lengths of the month and the year and how these work together to make the overall calendar.

[2] A luni-solar calendar has 29 & 30 day alternating months which always start at the same moon phase (usually new moon)

[3] Year has 12 months (12 x 29.5 = 354 days) in most years but adds 13th month in some years to stay close to seasonal cycle

b). (3 points). In the ancient Greek "*luni-solar*" calendar *Boedromion* is the month at harvest time. The Mystery rites of Eleusis started at the base of the Acropolis on the 15th day of *Boedromion.* What was the moon phase at the time the rites of Eleusis began?

[3] FULL MOON

c). (10 points total for part c) In order to keep exactly true to the seasons a *luni-solar* calendar has to include some **intercalation.**

c1). (3 points) Explain what is meant by intercalation.

[3] intercalation is the addition (or can be subtraction) of days or months to a calendar to keep the calendar in step with the heavenly cyles (usually Sun and/or Moon)

c2). (3 points) Explain why intercalation is required in a *luni-solar* calendar.

[3] $12 \times 29.5 = 354$ days which is 11+ days short of a Solar year; i.e., the year is NOT an even # of lunar months

c3). (4 points) Explain how intercalation is accomplished in a *luni-solar* calendar.

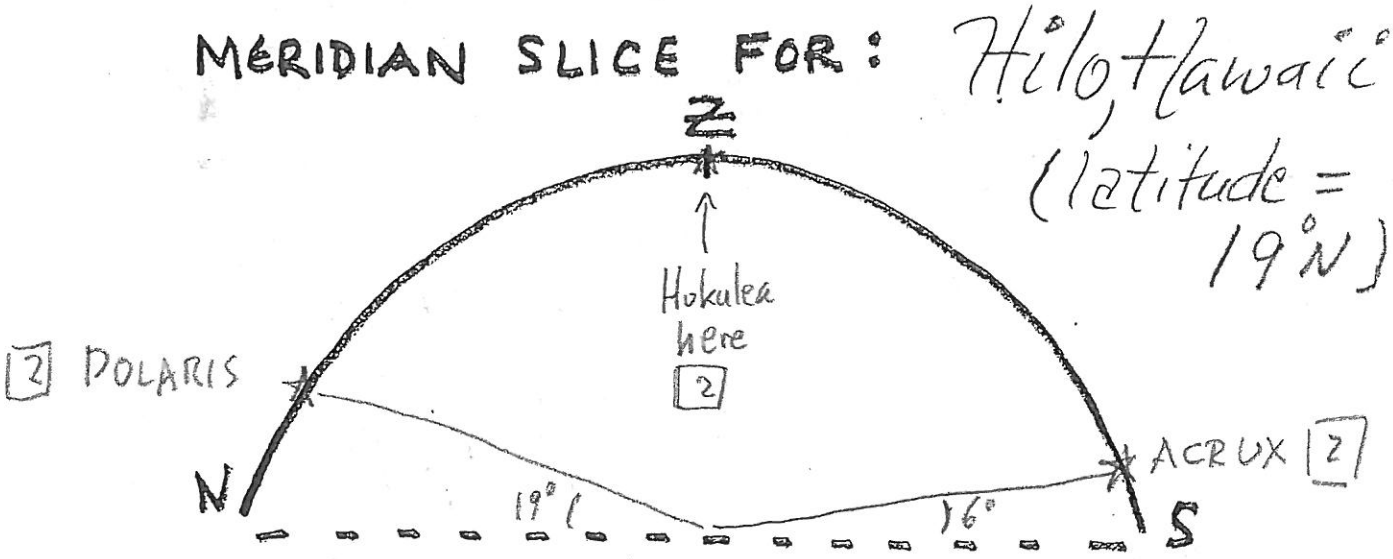
[3] a full month is added every 2-3 years

[1] over a 19 year period ("Year of Meton")

d). (4 points) The ancient Egyptian and Roman cultures kept a pure solar calendar. Was intercalation required in this calendar? If so, how was it accomplished? If not, why not?

[1] YES [3] The Solar year is not an even # of days ⇒ an extra day was added every 4 years

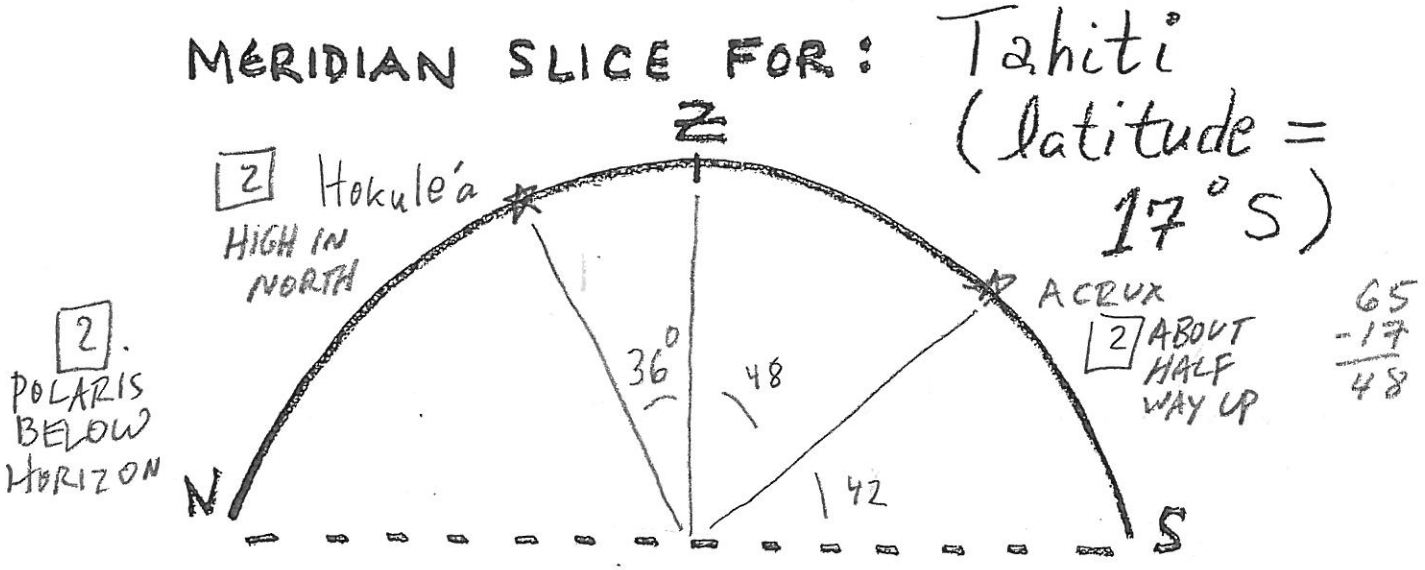
3. **CELESTIAL NAVIGATION** (23 points).The sketch below is a "*Meridian Slice*" diagram, a slice through the Celestial Sphere along the meridian. This one is set up for Hilo, Hawaii (latitude = 19° North).



a). (6 points). Locate the positions of the following **three** astronomical objects on the *Meridian Slice* above: (1). Hokule'a (Arcturus) @ 19° North Celestial Latitude; (2). ACrux (the brightest star in the Southern Cross, at the bottom of the upright cross) @ 65° South Celestial Latitude; and (3). Polaris @ 90° North Celestial Latitude.

ALTITUDE IS NOT REQUIRED AS LONG AS POSITION LOOKS REASONABLE

The *Meridian Slice* diagram below is set up for Tahiti at latitude = 17° S.



b a). (6 points). Locate the positions of the following **three** astronomical objects on the *Meridian Slice* above: (1). Hokule'a (Arcturus) @ 19° North Celestial Latitude; (2). ACrux (the brightest star in the Southern Cross, at the bottom of the upright cross) @ 65° South Celestial Latitude; and (3). Polaris @ 90° North Celestial Latitude.

c b). (6 points). Describe in words how a traditional Polynesian navigator (i.e., no compass, no sextant, no clock, no socks, no GPS) would use the information implicit in the *Meridian Slice* diagrams above to navigate from Tahiti to Hilo. A complete answer uses any 2 of the 3 objects you located on the Meridian Slices for navigational purposes.

#1 POSSIBILITY: Sail N until you see Polaris, continue N until Hokule'a goes overhead every night. Turn downwind keeping Hokule'a overhead each night. [Look for birds, clouds, etc] (not required)

Give liberal partial credit

#2 POSSIBILITY: same as above but instead of Hokule'a use Southern Cross when upright (on meridian) angle of ACRUX off horizon is same as long portion of S. cross (at left when A = B) then turn downwind as above.

A
B

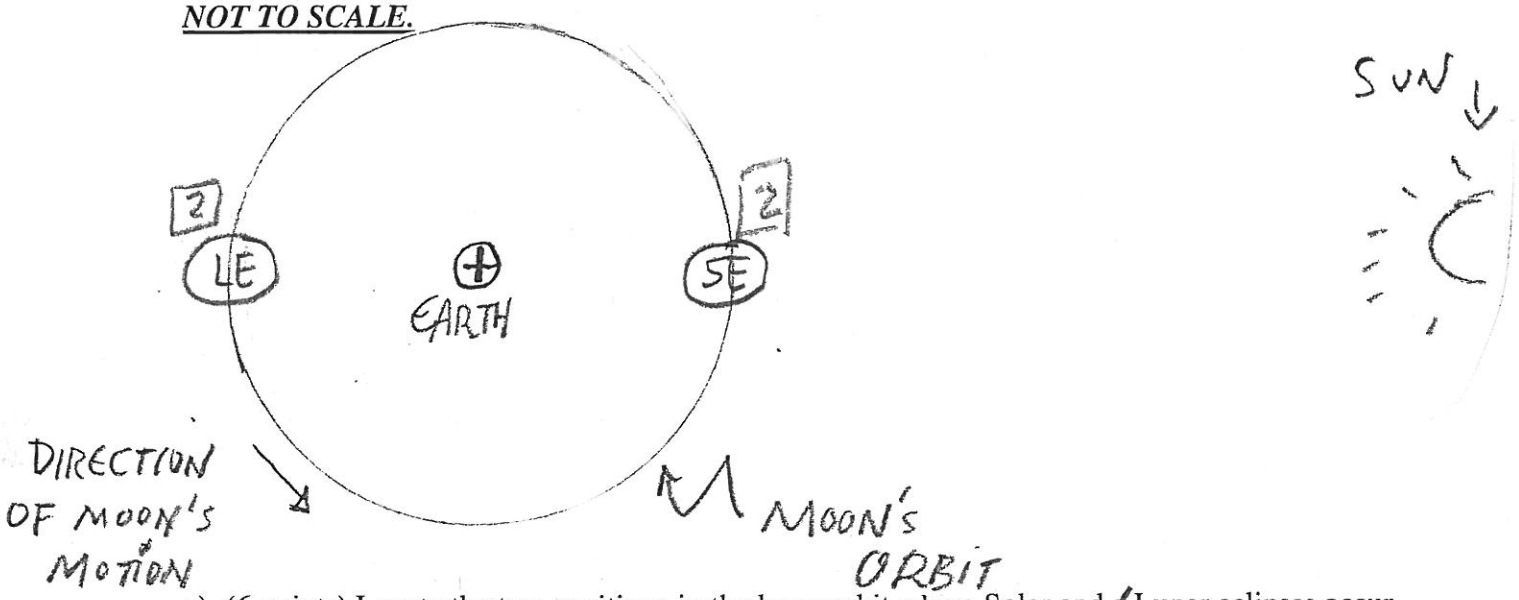
d c). (2 points). Traditional Polynesian navigational techniques can provide latitude information but not longitudes. What additional information is necessary to know longitude at sea?

[2] the time; a clock, preferrable on Greenwich time, is needed

e d). (3 points). In terms of the location of the Sun, what can happen in Tahiti and Hilo that never happens in Boulder, CO? Explain.

[3] Zenith Sun at noon or sun can cross meridian both north & south of the Zenith

4. **ECLIPSES** (30 points). The sketch below shows the Moon's orbit around the Earth from a location far from Earth and far above the ecliptic plane. The Sun is to the right and the sketch is ***NOT TO SCALE.***



a). (6 points) Locate the two positions in the lunar orbit where Solar and Lunar eclipses occur. Label these with an "SE" and an "LE" respectively. What are the moon phases at these two locations?

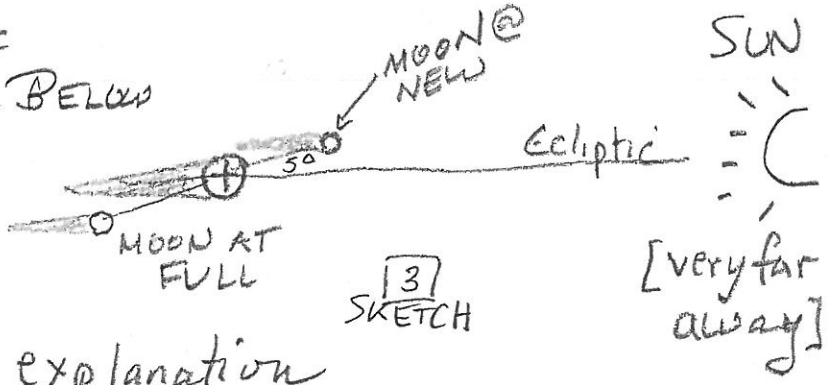
Solar Eclipse: New Moon [1]

Lunar Eclipse: Full Moon [1]

b). (6 points) Explain why eclipses do not occur every month. **A sketch is required** as part of your explanation.

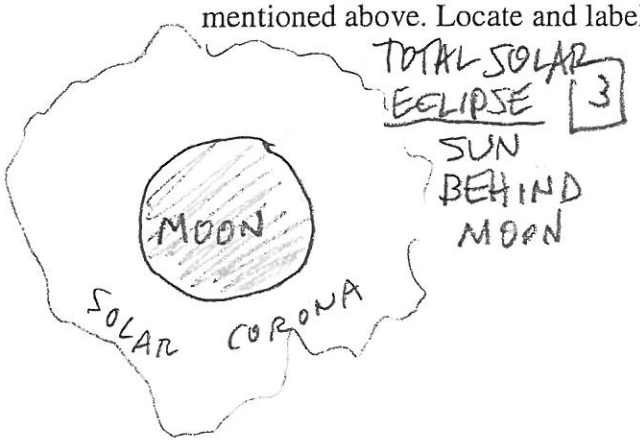
AT FULL MOON THE SHADOW OF THE ⊕ USUALLY FALLS ABOVE OR BELOW THE MOON ⇒ NO ECLIPSE

AT NEW MOON THE MOON'S SHADOW USUALLY MISSES THE ⊕ DUE TO 5° TILT OF LUNAR ORBIT ⇒ NO ECLIPSE [3] explanation



[3] SKETCH

c). (6 points) In the left hand side of the space below sketch the appearance of a total eclipse of the Sun as it would appear in the *Path of Totality*. On the right hand side of the space below sketch the appearance of this same eclipse if you were 500 miles south of the *Path of Totality* mentioned above. Locate and label the positions of the Sun & Moon in each of your sketches.



[3] PARTIAL SOLAR ECLIPSE

[SUN & MOON SHOULD BE ABOUT THE SAME SIZE]

d). (7 points total for part d) **Eclipse Seasons** are centered 173 days apart on the days when the Sun crosses the **lunar nodes**.

d1). (2 points) What are the **lunar nodes** and what do they have to do with eclipses?

[2] The lunar nodes are the two points where the Moon's & Sun's orbits cross in the sky. Eclipses can occur only at or close to the nodes.

d2). (3 points) What are the **Eclipse Seasons** and why are they 173 days, not 183 days apart (1/2 year)?

[2] Eclipse seasons are the 2-4 week period twice per year, when the Sun is close enough to one of the nodes for an eclipse to occur.

[1] They are <1/2 year apart because nodes move backwards through the calendar

d3). (2 points) Do eclipses of the Sun and Moon repeat every 173 days? Why or why not?

[1/2] NO

[1/2] 173 days is not an even # of lunar cycles.

5

e). (6 points) Some astronomers think that the ancient monuments *Stonehenge* in England and the *Sundagger* at Chaco Canyon in New Mexico were used to predict eclipses. At each site specific eclipse numerology is present; that is, specific numbers which are uniquely related to some aspect of eclipses. Choosing **EITHER** the *Sundagger* **OR** *Stonehenge* (***only one!***), explain **what number or numbers** specific to eclipses occur at the site, as well as where and how they occur in the site. Explain why these numbers **probably** indicate an interest in eclipse prediction amongst the builders.

Stonehenge – 56 Aubrey Holes = $18\frac{2}{3} \times 3$ (cycle of nodes in years). 56 chalk filled holes evenly spaced in a 300' diameter circle. Part of Stonehenge I [c.3200 BCE]
56 makes it easy to track the nodes (3 holes per year)

Sundagger – 9 to 9½ turn spiral ≈ ½ node cycle ≈ Eclipse season cycle & lunar standstill cycle. Shadow on spiral tracks shadow of winter full moon between minimum & maximum extreme full moons. Shadow moves one turn per year on the spiral

[liberal partial credit]

*** You **must** sign the honor code pledge for this examination to be graded and recorded ***

On my honor as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this work.

_____

Signature