ASTR 300 Stars and Stellar Systems Spring 2011

Homework Set No. 1 Due Feb 8, 2011

Please type up or print out your homework and staple the pages together. Leave a blank space to write in mathematical equations or diagrams. Make sure you **show your work** for any calculations – "magical" answers will receive no credit. Problems are **due at the beginning of the lecture**.

Review questions, Problems, etc. which have a chapter and number noted are from your text *Stars and Galaxies*.

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1. If the Earth did not rotate, could you define the celestial poles and celestial equator? (Chapt. 2, Review Question 8)

2. As the earth turns on its axis, an observer on the earth's surface sees the sun, moon and stars (except for *circumpolar* stars) rise in the east, traverse the sky, and set in the west. All these objects reach their highest point above the horizon when they cross the **meridian**. For an observer in the northern hemisphere, the meridian is the arc that passes from the north point on the horizon, up through the north celestial pole, through the zenith overhead, and on down to the south point of the horizon. The angular distance along the meridian from the northern horizon up to the north celestial pole (NCP) is equal to the latitude, ϕ, of the observer.

   (a) For an observer in College Park, the latitude is $\phi = 39^o$. The celestial equator is 90^o from the NCP. On March 20 (the *vernal equinox*) the sun will be on the celestial equator. How high above the southern horizon will the sun be when it crosses the meridian on March 20?

   (b) On June 21 (the *summer solstice*) the sun is 23.5^o above the celestial equator, while on December 22 (the *winter solstice*) the sun is 23.5^o below the celestial equator. How high is the sun above the southern horizon when it crosses the meridian on June 21? How high is it when it crosses on December 22?

3. If a beam of light with a cross-section of one square meter makes an angle of θ with a surface, then that beam will be spread out over an area of $1/\sin(\theta)$ square meters when it strikes the surface. Thus the heating of the surface will be reduced by a factor of $\sin(\theta)$ compared to the heating that would be produced by a beam shining straight down ($\theta = 90^o$).

   (a) Using your results from Question 2 above, how much is the heating by the sun reduced on March 20 compared to a point on the earth's surface where the sun is directly overhead?

   (b) By what factor is the sun's heating on June 21 greater than the heating on December 22 at College Park?

4. The apparent visual magnitude of the sun is -26.8 (Table A-9). The magnitude of Sirius, the brightest star, is -1.47. (Also, see Figure 2-6 on p 15.) By what factor is the sun brighter than Sirius? (Hint: use the equation on page 16 of the text.)

5. After the α Centauri system, the nearest star to our solar system is Barnard's Star, which is 5.9 ly distant (see Table A-9, p 424). But the apparent visual magnitude of Barnard's star is $m_V = 9.5$, much too faint to be seen with the naked eye. If a star must have a magnitude of 6.5 to be seen with the naked eye, by what factor would the brightness of Barnard's star have be increased to become visible? Considering the inverse square dependence of brightness on distance, how close would Barnard's star have be to become visible?

   Barnard's star is actually moving towards us at 107 km/s, and in about 10,000 years it will pass within 3.8 ly of us; after that its distance will increase again. When it is 3.8 ly away it will be the nearest star. Will it be visible to the naked eye then?

6. Both the Earth and the Moon orbit their common center of mass, but since the Earth is much more massive, its orbit is much smaller that that of the Moon. Look up the mass of the Earth and of the Moon in Table A-5 (p 422). How much more massive is the Earth than the Moon? (I.e., what is the ratio of their masses?)

   Look up the distance from the Earth to the Moon in Table A-11. Calculate the distance of the Earth's center from the center of mass of the Earth-Moon system. Express this distance in units of the Earth's radius.

7. We saw that the true form of Kepler's third law can be written

$$P^2 = \frac{a^3}{m_1 + m_2}$$

   if we express the period P in years, the semi-major axis a in astronomical units (AU), and the masses of the two bodies, m_1 and m_2, in solar masses. (If the orbit is circular, then $a = r$, the distance between the two bodies.)

   Consider a satellite orbiting the Earth. What is the mass of the Earth in solar masses? You can neglect the mass (m_2) of the satellite.

   The Hubble Space Telescope (HST) is in a relativity low orbit, 560 km above the Earth's surface. What is the radius of the HST's orbit? What is this radius in AU (1 AU = 1.496×10^8 km)? Now use the equation to find the period P of the HST's orbit in years. Finally, convert your answer to minutes (there are 525949 minutes in a year).

   Suppose we could triple the height of the Hubble's orbit to 1680 km above the Earth's surface. What would it's new orbital period be?