Astro 102, Fall 2006 — Review Problems #3

Possibly Useful Constants and Formulae

$$R_\odot = 6.96 \times 10^5 \text{ km}$$
$$M_\odot = 1.99 \times 10^{30} \text{ kg}$$
$$L_\odot = 3.8 \times 10^{26} \text{ W}$$
$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$
$$h = 6.626 \times 10^{-34} \text{ J s}^{-1}$$
$$1\,\text{pc} = 3.26 \text{ lyr}$$
$$1\,\text{pc} = 206,265 \text{ AU}$$
$$1\,\text{pc} = 3.086 \times 10^{16} \text{ m}$$
$$1\,\text{AU} = 1.496 \times 10^{11}\,\text{m}$$
$$1\,\text{km} = 1,000\,\text{m}$$

$$E = m\,c^2$$
$$\lambda\,f = c \qquad f = \frac{c}{\lambda} \qquad \lambda = \frac{c}{f}$$
$$E = h\,f$$
$$L = A\,\sigma\,T^4$$
$$L = (4\pi\,R^2)\,\sigma\,T^4$$
$$B = \frac{L}{4\pi\,d^2}$$
$$z = \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{\text{obs}} - \lambda_{\text{orig}}}{\lambda_{\text{orig}}}$$
$$z = \frac{v}{c} \quad (\text{for v} \ll \text{c})$$

Age of Solar System:	4.6×10^9 years
Age of Universe:	13.7×10^9 years
Lifetime of 1 $M_\odot$ star (type G on main sequence):	10^{10} yr (10 Gyr)
Lifetime of 3 $M_\odot$ star (type A on main sequence):	4×10^8 yr (400 Myr)
Lifetime of 8 $M_\odot$ star (type B on main sequence):	4×10^7 yr (40 Myr)
"High-mass" star (will go supernova):	$M > 8\,M_\odot$

1. Betelgeuse is a red M-type star. Vega is a white A-type star. They have similar brightnesses as observed from Earth. From just this information, can you say anything as to whether Vega or Betelgeuse is farther away? Explain.

2. Consider a cluster of stars all formed at once. This cluster has a typical distribution of stars with mass, i.e. there are only a few high-mass stars ($> 8\,\text{M}_\odot$), but a lot of low-mass stars ($< 8\,\text{M}_\odot$), with lower and lower mass stars more and more common.

Make a plot. On one axis should be *time*, running from $t = 0$ (when the cluster forms) to 100 million years. On the second axis should be a number of stars (using an arbitrary scale). Knowing that high-mass stars live at most a few times 10 million years, draw two lines on your plot. The first line should be the number of *neutron stars* in the cluster as a function of time, the second line should be the number of *white dwarf* in the cluster as a function of time.

3. Most stars show a spectrum that is a blackbody continuum with absorption lines.

(a) Make a sketch of intensity vs. wavelength for a star's spectrum.

(b) What part of the star is responsible for the absorption lines? Draw a picture if this helps you explain.

4. Consider three surveys of main sequence stars in our Galaxy. All three surveys detect all stars above a certain brightness. Survey A is sensitive enough to detect all main-sequence stars of spectral classification A out to a distance of 3kpc. Survey B is sensitive enough to detect all main sequence stars of spectral classification A out to a distance of 30kpc. Survey C is sensitive enough to detect all main sequence stars of spectral classification K out to a distance of 30kpc.

Recall that 30kpc is approximately the size of our Galaxy.

For each of the questions below, consider the ratio of A-type stars to K-type stars detected by each survey,

$$\frac{N_A}{N_K}$$

(a) Qualitatively, how does the ratio N_A/N_K compare between Surveys A and B? (Are the ratios the same in the two surveys, or is the ratio bigger on one?)

(b) Qualitatively, how does the ratio N_A/N_K compare between Surveys A and C? (Are the ratios the same in the two surveys, or is the ratio bigger on one?)

(c) Qualitatively, how does the ratio N_A/N_K compare between Surveys B and C? (Are the ratios the same in the two surveys, or is the ratio bigger on one?)

5. A friend walks up to you and asserts, "I just learned about blackbody radiation from a web page. From that, now I know that all of the brightest stars you see in the sky at night are going to be the hottest stars."

(a) Suppose you knew *nothing* about blackbody radiation; you accept that there is some correlation between luminosity and temperature, but you don't know which way it goes. You do know the relationship between luminosity, brightness, and distance. Would you agree with this friend, or disagree with this friend? Explain.

(b) Suppose now you know what you know about blackbody radiation, but don't know about the H-R diagram. Would you agree with this friend, or disagree with this friend? Explain.

(c) Given what you know about the H-R diagram and what stars are out there, what *are* the brightest stars you see in the sky? (Talk about both temperature (or spectral classification) and whether the stars are dwarfs, main sequence, or giant stars.)

(d) Is this story plausible? Specifically, do you have any friends?

6. **(a)** If the radius of the Sun were to double while keeping its surface temperature the same, what would be its luminosity (in W)? Qualitatively, how would the color of the Sun change?

(b) If the temperature of the Sun were to double while keeping its size the same, what would be its luminosity (in W)? How would the color of the Sun change?