Exam #2
79205 Astronomy
Fall 1997 NAME: ___Solution Key____

You have two hours to complete this exam. There are a total of five problems and you are to solve all of them. *Not all the problems are worth the same number of points.*

You may use *Introductory Astronomy and Astrophysics* (Zeilik & Gregory), *Astronomy: The Evoloving Universe* (Zeilik), and class notes and handouts, or other books. You *may not* share these resources with another student during the test.

Indicate any figures or tables you use in your calculations. Show all Work!

GOOD LUCK!

Problem	Score	Worth
1.	________	20
2.	________	15
3.	________	20
4.	________	25
5.	________	20
Total Score:	__________	100

Problem 1 (20 points): Following are 10 brief descriptions of stars. For each one, choose the *one* spectral type which *most closely* describes the star. Not all of the spectral types must be used, and you may use some more than once. <u>Indicate your choice with the lower case letter used below:</u>

a: O8V **b:** B5I **c:** A0V **d:** A5I **e:** F3I **f:** G2V **g:** K3V **h:** K3III **i:** M5I

__h__ **1.** Spectrum has strong, narrow calcium lines

__f__ **2.** The Sun

__c__ **3.** Continuum part of the spectrum peaks at 290 nm

__i__ **4.** Coolest surface temperature in the list

__i__ **5.** Largest radius star in the list

__c__ **6.** Strongest hydrogen lines in the list

__a__ **7.** A very massive star with weak hydrogen lines

__g__ **8.** A star with a smaller radius than the Sun

__e__ **9.** Surface temperature close to 7000 K

__b__ **10.** Hydrogen and helium lines with about equal strength

Problem 2 (15 points): Calculate the effective surface temperature of a star with radius $1.39{\times}10^9$m and which radiates $1.56{\times}10^{27}$ Joules per second, integrated over all wavelengths.

This could be done directly from the Stefan-Boltzmann law ...

$$L = 4\pi R^2 \sigma T^4 = 4\pi(1.39\times10^9)^2 \sigma T^4 = 1.56\times10^{27}$$

... which leads to $T \cong 5800\ \mathrm{K}$ with everything in SI units.

A different way is to write it all in terms of solar units, that is ...

$$\frac{L}{L_{SUN}} = \frac{4\pi R^2 \sigma T^4}{4\pi R_{SUN}^2 \sigma T_{SUN}^2} = \left(\frac{R}{R_{SUN}}\right)^2 \left(\frac{T}{T_{SUN}}\right)^4$$

... which reduces to

$$4 = (2)^2 \left(\frac{T}{T_{SUN}}\right)^4$$

or just $T = T_{SUN} \cong 5800\ \mathrm{K}$

Problem 3 (20 points): An A0 main sequence star has an apparent visual magnitude of 12.5 and an apparent blue magnitude of 13.3. The spectral class is assigned using the absorption lines.

a (2 points) What is the value of the observed color index *B-V*?

B-V = 13.3 - 12.5 = 0.8

b (3 points) What is the value of the intrinsic color index *B-V*?

B-V = 0 for an A0 main sequence star; See also Table A4-3 in Zeilik.

c (3 points) What is the value of the star's absolute visual magnitude?

M_V = + 0.6 from Table A4-3 , or $M_V \approx +1$ from an HR diagram in *absolute* magntiude, like Fig. 13-9C, 13-11B, or the left axis on 13-14B.

d (4 points) Estimate the distance to the star if there were no interstellar reddening.

$12.5 - M_V = 5 \log d - 5$ leads to d=2.4 kpc (M_V = + 0.6) or d=2.0 kpc (M_V = +1)

e (8 points) Estimate the distance to the star including interstellar reddening, based on the data given in this problem.

With interstellar reddening, we modify the distance formula to be

$$12.5 - M_V = 5 \log d - 5 + A_V$$

where we can determine A_V from the amount of reddening, that is

$$A_V = 3\,(0.8 - 0) = 2.4$$

which leads to d = 738 pc (for M_V = + 0.6).

Problem 4 (25 points): Two stars form an eclipsing binary pair, viewed edge on. Star #1 has a surface temperature of 15,000 K and star #2 has a surface temperature of 5000 K. The cooler star is a giant with a radius four times as large as the hotter star.

a (5 points) Is the primary (deeper) intensity minimum found when star #2 eclipses star #1, or the other way around? Explain your reasoning.

When both stars are visible, the luminosity is $L=L_1+L_2$ where

$$\frac{L_1}{L_2} = \left(\frac{R_1}{R_2}\right)^2\left(\frac{T_1}{T_2}\right)^4 = \frac{81}{16}$$

that is, star #1 is much brigher than star #2. The deepest minimum in intensity therefore happens when star #1 is behind star #2.

b (5 points) Find the ratio of the luminosity L_P at the <u>primary</u> minimum to the maximum luminosity L.

The luminosity at the primary minimum is just L_2 since star #1 is hidden. Therefore

$$\frac{L_P}{L} = \frac{L_2}{L_1 + L_2} = \frac{1}{81/16 + 1} = \frac{16}{97} = 0.165$$

c (10 points) Find the ratio of the luminosity L_S at the <u>secondary</u> minimum to the maximum luminosity L.

This is trickier since not all of star #2 is hidden at the secondary minimum because it has a larger radius. The fraction of the surface area that is hidden is just $(R_1/R_2)^2 = 1/16$ so

$$\frac{L_S}{L} = \frac{L_1 + \frac{15}{16}L_2}{L_1 + L_2} = \frac{81/16 + 15/16}{81/16 + 1} = \frac{96}{97} = 0.9897$$

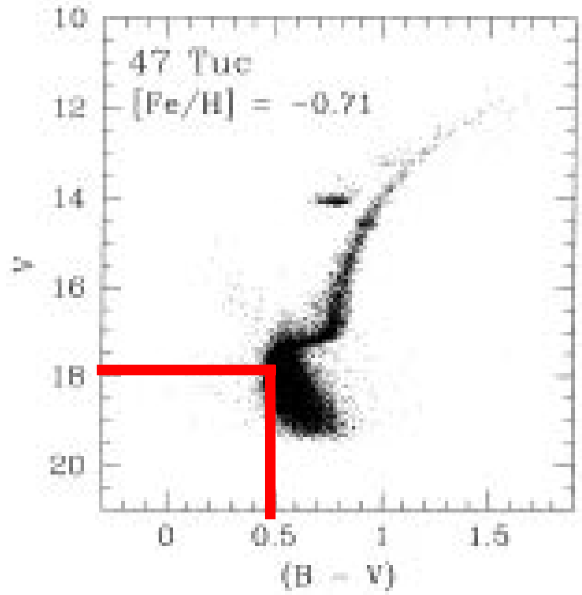
d (5 points) What is the change in magnitudes at the <u>primary</u> minimum?

Since both stars in the binary system are at the same distance, the difference in magnitudes is just derived from the log of the ratio of the luminosities. That is

$$\Delta m = 2.5\log\frac{L}{L_P} = 1.96$$

Problem 5 (20 points): The figure shows a color-magnitude HR diagram of the globular cluster 47 Tuc.. The figure is from Rich, et al, Astrophysical Journal 484 (1997)L25.

a (15 points) Use the figure to estimate the distance to the globular cluster. You can ignore the effects of interstellar reddening.



This is just like calculating the distance to the Pleiades, which we did in studio, but in globular clusters, only the low mass stub of the main sequence is visible. You can use any point on that stub to get the distance. For example, at B-V=0.5, the apparent visual magnitude V ≈ 18. The absolute visual magnitude for a main sequence star with B-V=0.5 can be gotten from, for example, Fig.13-15 (for which my eye says $M_V \approx +5$) or by interpolating from Table A4-3 (for which B-V=0.5 seems to correspond to around F7 on the main sequence, so $M_V \approx +4$). Therefore

$$18 - M_V = 5 \log d - 5$$

implies d = 3.98 kpc (for $M_V \approx +5$) or d = 6.31 kpc (for $M_V \approx +4$).

b (5 points) Is this a reasonable value for the distance? Explain your reasoning.

This *is* a reasonable value (which is good since the data was taken from a real paper in the Astrophysical Journal). Globular clusters hang out surrounding the center of our galaxy, outside the galactic plane. We are around 8.5 kpc from the galactic center, so it makes sense that a globular cluster should be several kpc away from us.