July 7, 2006 Name:________________________

Astronomy 102: Stars and Galaxies

FINAL EXAM REVIEW

Instructions: Write your answers in the space provided. If you need additional space, continue on the back of each page, but indicate **clearly** that you have done so. No books, notes, or assistance from anyone is allowed. You are allowed to use, and will need, a calculator. Please **write legibly and be brief and to the point!** The exam has seven questions; each question has equal weight.

Possibly Useful Constants and Formulae

$$R_{\rm Earth} = 6,378 \text{ km}$$
$$R_\odot = 695,500 \text{ km}$$
$$L_\odot = 3.8 \times 10^{26} \text{ W}$$
$$d_\odot = 1\,\text{AU} = 1.496 \times 10^{11}\,\text{m}$$
$$L_{\rm Vega} = 55\,L_\odot$$
$$d_{\rm Vega} = 7.8\,\text{pc}$$
$$M_{\rm Vega} = 3\,M_\odot$$

$$1\,\text{Mpc} = 10^6 \text{ pc}$$
$$1\,\text{pc} = 3.26 \text{ lyr}$$
$$1\,\text{pc} = 206,265 \text{ AU}$$
$$1\,\text{pc} = 3.086 \times 10^{16} \text{ m}$$
$$1\,\text{km} = 1,000\,\text{m}$$

Age of Solar System: 4.6×10^9 years
Age of Universe: 13.7×10^9 years

High Mass Star : $M_* > 8\,M_\odot$

O B A F G K M
← bluer redder→
← hotter cooler→

$$L = A\,\sigma\,T^4$$
$$L = 4\pi {R_\odot}^2\,\sigma\,T^4$$
$$B = \frac{L}{4\pi\,d^2}$$
$$\sigma = 5.67 \times 10^{-8}\,\text{W}\,\text{m}^{-2}\,\text{K}^{-4}$$

$$d = \frac{1}{p} \quad d \text{ in pc, } p \text{ in } ''$$

$$z = \frac{d}{c\,t_H} \quad (\text{For } z \ll 1)$$
$$z = \frac{\lambda_{\rm obs} - \lambda_{\rm orig}}{\lambda_{\rm orig}}$$
$$z = \frac{v}{c} \quad (\text{For } v \ll c)$$
$$z = \frac{\text{Size Now}}{\text{Size Then}}$$

$$t_H = 13.8 \times 10^9 \text{ yrs} = 4.35 \times 10^{17} \text{ s}$$

$$c = 3.00 \times 10^8 \text{ m s}^{-1} = 1 \text{ lyr yr}^{-1}$$

Lifetime of $8\,M_\odot$ star : 50 million years
Lifetime of $3\,M_\odot$ star : 500 million years
Lifetime of $1\,M_\odot$ star : 10 billion years

1. The half-life of Potassium-40 is about 1.26 billion years. Consider some descendants of ours who measure the concentration of Potassium-40 in the oldest meteorites, and find that it is just a little more than 1/16 what we see right now.

- **(a)** How many half-lives have elapsed between now and the time the descendants make the measurement? Therefore, how many years in the future is it?
- **(b)** What does the Sun look like to these descendants of ours?

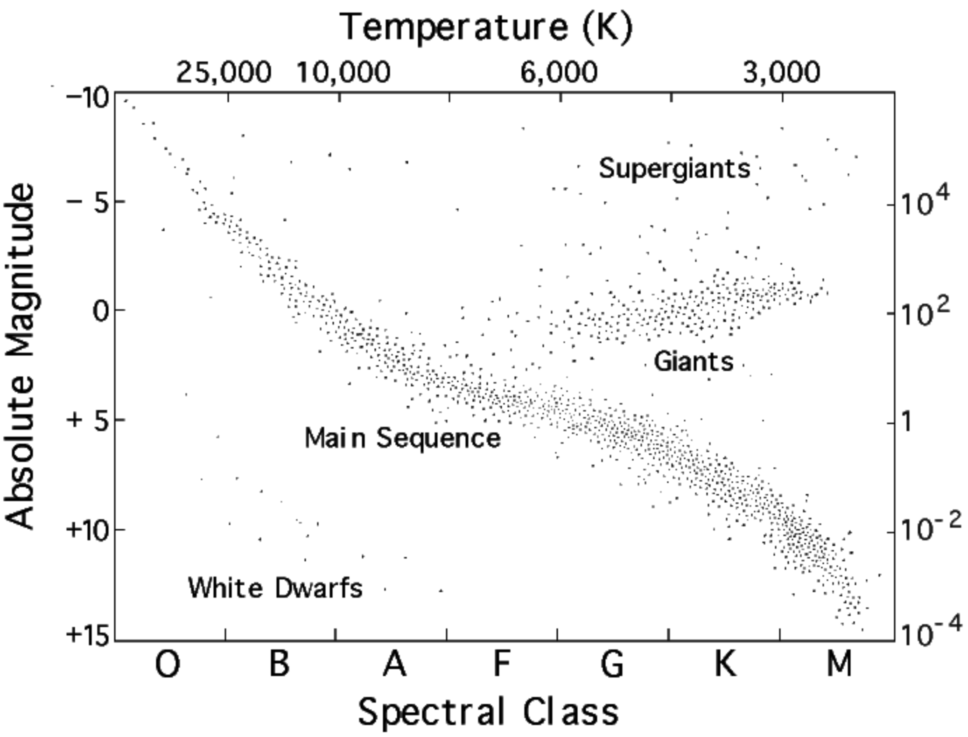
2. One of the closest quasars is 3C273. This quasar has a measured redshift of $z = 0.158$.

- **(a)** Although this isn't quite right, assume that $0.158 \ll 1.0$, and that the d in the Hubble Law is the current distance. How far away is 3C273?
- **(b)** Using your answer from (a), how far away was 3C273 when the light we see from it was emitted?
- **(c)** Being a quasar is a phase that the largest of galaxies go through. This phase tends to last about 100 million years. We see 3C273 as a quasar today; is 3C273 likely really a quasar today? Explain.

3. The Cosmological Principle, loosely stated, says that "we are nowhere special." More precisely, it says that the Universe is "isotropic" (the same in all directions) and "homogenous" (the same everywhere).

- **(a)** Obviously, however, the region of the Universe in this room and the region of the Universe at the center of the Sun are very different. Does this invalidate the Cosmological Principle? Explain briefly.
- **(b)** Broadly speaking, the Universe is made up of Normal Matter, Dark Matter, and Dark Energy. One of these is spread evenly througout the Universe; one clumps into galaxies, but is spread fairly evenly within galaxies; the other is mixed up in different places of galaxies and sometimes clumps into relatively small lumps. Which is which? What are the lumps mentioned for the last component?

4. Consider the H-R diagram below:



(a) Mark a point on the diagram labelled with "A" that corresponds to a star which is currently burning Hydrogen at its core, but will only live for about 10 million years.

(b) Mark a point on the diagram labelled with "B" that corresponds to a star that will live for about 500 million years.

(c) Mark a point on the diagram labelled with "C" that corresponds to a star that wlil live for about 10 billion years.

(d) Shade in an area, or draw a line or set of lines, that correspond to the region on the diagram that will be occupied by observations of stars in a cluster that formed more than 10 billion years ago.

(e) Explain the concept of "main sequence turnoff" and how it relates to figuring out the age of a cluster of stars.

5. High mass stars, after their life is done, leave behind a neutron star (or, rarely, a black hole), whereas low mass stars leave behind a white dwarf. Low mass stars are much more common than high mass stars. However, if you estimate the number of neutron stars and white dwarfs there should be in our galaxy, you find that the ratio of the number of neutron stars to white dwarfs, while still small, is *larger* than the ratio of the number of high mass stars to low mass stars. How can you explain this disparity?

6. You observe a star in the sky whose spectrum indicates that it is just like Sirius. Sirius appears 25 times brighter than this other star. Sirius has a parallax of $0.38''$.

(a) How far away (in pc) is Sirius?

(b) How far away (in pc) is the other star?

(c) A parallax measuring spacecraft (PMS) is launched, which measures the parallax of the other star to be $0.008''$. Is this measurement consistent with your previous estimate? If so, explain why. If not, suggest a possible reason for the discrepancy (assuming that everybody's data was correct).

7. A certain binary star system consists of a white dwarf and a red giant orbiting each other. Assume the white dwarf has a radius of 1 R_{Earth}, and the red giant has a radius of 100 $R_{\odot}$. The white dwarf's surface temperature is 6,000 K, and the red giant's surface temperature is 3,000 K. This is a binary star system where the two stars formed together, at the same time.

(a) What is the ratio B_W/B_R of the observed brightness of the white dwarf to the observed brightness of the red giant?

(b) Is it possible that both the red giant and white dwarf have the same mass? Explain; be sure to consider the comparison of the stars' masses when they were both first formed.

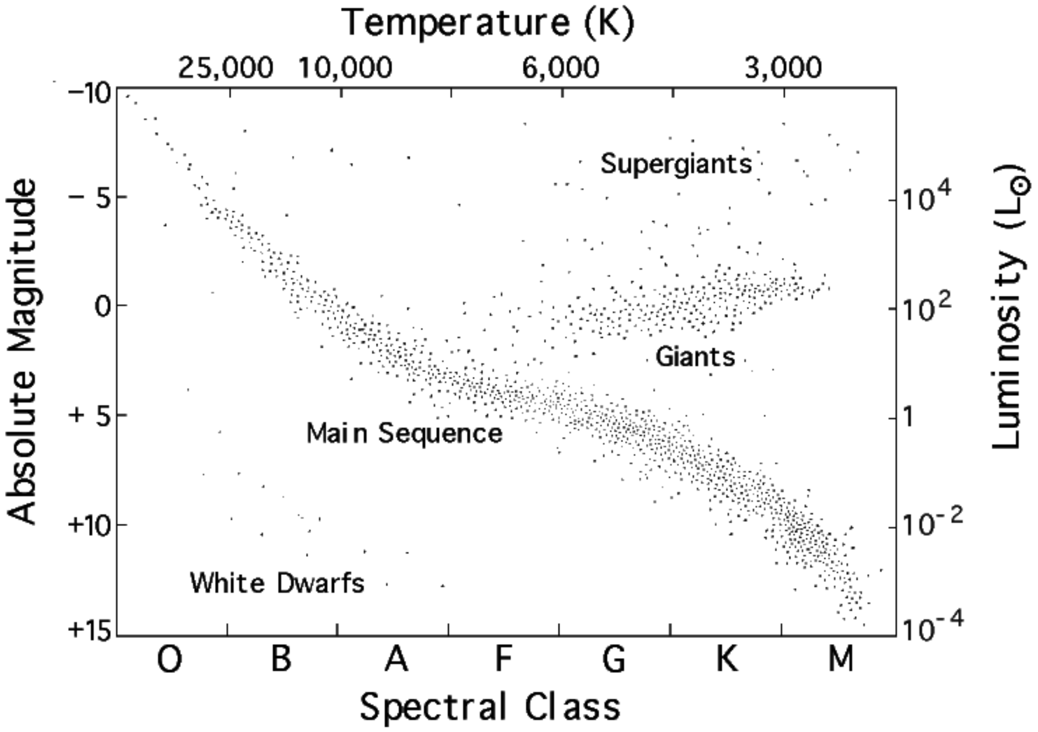
(c) Suppose this binary star system is 200 parsecs away. How far away would another identical white dwarf need to be to have the same brightness as the red giant in the progenitor system?

8. [6 points] Albireo, or γ Cygni, is one of the prettiest double stars in the sky. It is a binary system with two stars very slowly orbiting each other over the course of thousands of years. They are separated enough such that they are easily resolved in a small telescope. In your lab telescopes, they show a strong color contrast, one being golden yellow and the other blue. The golden yellow star is brighter than the blue star.

(a) From this description, what can you say about the relative sizes, luminosities, and temperatures of the two stars?

(b) Two stars which are in orbit will almost always have formed together. Given this, what can you say about where each star is along its evolution? Suggest a possibility for what type each star is that would be consistent with the observations as described above.

9. Plot each of the following on the H-R diagram below, labelled with the appropriate letter:



(a) The Sun.

(b) A whitish star ($T = 9,000$ K) that is 2.4×10^{-12} times as bright in our sky as the Sun, with a parallax of $0.1''$.

(c) A reddish star ($T = 3,000$ K) whose radius is 80 times the radius of the Sun.

(d) A whitish star ($T = 9,000$ K) that has a radius similar to the radius of the Earth.

(e) A star fusing Hydrogen at its core that will only live about 10 million years.

(f) A red star that has a parallax of $0.75''$ and is 4×10^{-14} as bright in our sky as the Sun.