ASTR 300 Stars and Stellar Systems Spring 2011

Homework Set No. 5 Due Apr 7, 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, 7th edition*.

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1. The table in Figure 12-2 of your text (p 234) is from a computer model of the solar interior. A far more detailed table is given on the class web page; the table can also be found at this web address:

   http://www.sns.ias.edu/∼jnb/SNdata/Export/BS2005/bs05_agsop.dat

   This model also includes the relative abundance of hydrogen, helium (^{4}He and ^{3}He) and some other isotopes. The star is divided into over 1000 zones, and the list starts at the center of the sun and goes outward (the table in Fig 12-2 goes from the surface inwards).

   (a) Compare the values in Fig 12-2 at a fractional radius of $R/R_\odot$ = 0.1 with the detailed model – how close are they? The columns called "X" and "Y(He4)" represent the fractional abundance, by mass, of H and ^{4}He. What are these values at $R/R_\odot$ = 0.1 ? How do they compare to the values at the sun's surface (which reflects the sun's original composition)? How do you explain the difference?

   (b) The element with the highest density is osmium. It has a density of 22.6 gm/cm^3, twice as dense as lead. Yet the H and He inside the sun can be much denser. At what radius is the density of the solar material equal to that of osmium? What is the temperature at that point? Is that temperature high enough for hydrogen fusion?

   (c) In the inner part of the sun, energy flows outward by radiation. But at about $R/R_\odot$ = 0.7, the material becomes too opaque and the convective zone begins. What is the temperature and density at this transition point? What fraction of the sun's mass is contained in the convective zone (the outer 30% of the sun's radius)?

   (d) What is the temperature and density in the zone where the abundance of the light helium isotope ^{3}He (He3) is greatest?

2. Why do some astronomers say that brown dwarfs are not really stars? Why are brown dwarfs hard to study?

3. We saw there is a mass-radius relation for white dwarfs (see slide 12 from lecture 16). What is the mass of a white dwarf with the same radius as the Earth? The force of gravity is given by $g = GM/R^2$ for a body of mass M and radius R. By what factor is the gravity on the surface of a white dwarf greater than that on the Earth, if the two have the same radius?

4. Look again at slide 12 from lecture 16. What is the radius of a 0.5 $M_\odot$ white dwarf? What is the radius of a 1 $M_\odot$ white dwarf? (Use the formula to calculate your results and check them against the graph.) Why is there no reference to the surface temperature of the white dwarf in this diagram? If these two dwarfs have the **same** temperature (say 10,000 K), which is more luminous? What is the ratio of their luminosities?

5. What happens to the radius of a white dwarf as it cools off? A white dwarf with a surface temperature of 18,000 K has a luminosity of 1/100 $L_\odot$. What is the radius of this object (in solar radii)? (Hint: Use the equation on slide 17 from lecture 4, not the mass-radius relation.) When it has cooled to 9000 K, what will its luminosity be then?

6. If the stars at the turnoff point in a star cluster are of spectral type F0, about how old is the cluster?

7. Use the formula in chapter 12 of your text to compute the life expectancy of a 0.4 solar-mass star. Why might this be an underestimate if the star is fully mixed?
(Chapter 13, Problem 1)

8. Presumably, all the white dwarfs in our galaxy were produced by sun-like stars of medium mass. Why couldn't any of these white dwarfs have been produced by the deaths of the lowest mass stars?
(Chapter 13, Review Question 2)

9. The coolest stars at the centers of planetary nebulae are about 25,000 K. Why don't astronomers see planetary nebulae with cooler central stars? (Hint: What kind of photons excite the gas in a planetary nebula?)
(Chapter 13, Review Question 5)