

## Ay 101 - The Physics of Stars – fall 2015 - J. Cohen

Homework 1, due Friday Oct 9 at class (2 pm)

1. (10 points) LeBlanc problem 1.12.

At a certain depth in a star, three ions of a given element have the following ionization fractions:  $f_1 = 0.10$ ,  $f_2 = 0.85$ , and  $f_3 = 0.05$ . Their partition functions (degeneracies) are  $g_1 = 1$ ,  $g_2 = 2$ ,  $g_3 = 8$ . The ionization energy from the fundamental level for ion 1 is 30 eV, and it is 55 eV for ion 2. Calculate  $n_e$  and  $T$ .

2. (10 points) Calculate (approximately) for the Sun the gravitational potential energy, the thermal energy, the rotational energy (assume solid body rotation), the kinetic energy of the bulk flows in the surface convective zone (5% of the total mass of the Sun, moving at 1.5 km/sec), and the energy in magnetic fields (assume the average surface magnetic field of 1 Gauss is uniform throughout the Sun).

b) Calculate the ratio of gas to radiation pressure at the center of the Sun.

c) We have ignored certain physical phenomena in class (rotation, magnetic fields...) in discussing stars similar to the Sun. Are we safe in doing so ?

3. (10 points) a) Calculate the pressure of the electrons  $P_e$  at the center of the Sun, first using the normal gas law and then assuming the electrons are degenerate. If  $P_e(\text{degen}) > P_e(\text{normal gas})$ , then the electrons in fact are degenerate. Based on your results, do you think that the electrons at the center are degenerate or not ?

b) Repeat this for the center of a white dwarf star. Assume the central density is 10 times the mean density, and the mass is 1.4 solar masses, the radius is  $10^{-2}$  solar radii, the composition is pure He ( $\mu_e = 2$ ), and the central temperature is  $5 \times 10^6$  K.

4. (15 points) We are looking for planets around nearby stars. Assume a star has one planet that is identical to Jupiter and is located at the same distance that Jupiter is located from

the Sun. Assume that the star is identical to the Sun. Assume the system is a distance  $d$  from the Earth. Assume both Jupiter and the Sun radiate as black bodies with their appropriate temperature (use: Sun 5780 K, Jupiter 150 K).

- a) What is the angular size corresponding to the planet-star distance ?
- b) What is the percentage change in the flux detected at the Earth from the star if the planet goes in front of the star as compared to the total light from the planet and the star ? The same for when the planet is behind the star ? (at a wavelength of 0.5 microns, then try the same at 20 microns)
- c) What is the orbital speed of this planet around its star ?
- d) What is the radial velocity amplitude seen in the star from the reflex motion caused by the Jupiter-like planet ? How does this scale with the mass of the planet ? What is the amplitude for an Earth mass planet at the same distance from the star ?
- e) Based on the above, what do you think might be a good way to try to find solar systems and planets around other stars ?