ASP3012: Stars and Galaxies
Stars Exercise Sheet 1

Q1.   a) Calculate the average energy generation ϵ for the Sun in
      i) erg/gm/sec
      ii) erg/cm^3/sec.
      iii) Using the results above calculate the mean density of the Sun.
  b) Repeat part (a) for a massive blue giant, with $M = 20M_\odot$ and $R = 6R_\odot$.
  c) Repeat part (a) for a low mass brown-dwarf, with $M = 0.1M_\odot$ and $R = 0.2R_\odot$.

Q2. We have estimated that in the centre of the Sun the temperature is $\sim 10^7$K. Hence calculate an average temperature gradient for the Sun (in degrees K/cm). Given that the mean-free path travelled by a photon in the Sun's interior is of order 2 cm (!) before it is absorbed and the re-emitted, calculate the typical change in temperature seen by a photon. Hence calculate the *relative* anisotropy of the radiation energy density. [Conclusion: matter must be in thermal equilibrium in stellar interiors.]

Q3. Consider the free-fall and Kelvin Helmholtz timescales. Write these in the forms

$$t_{ff} = a \left(\frac{R}{R_\odot} \right)^{3/2} \left(\frac{M}{M_\odot} \right)^{-1/2} \text{seconds}$$

and

$$t_{KH} = b \left(\frac{M}{M_\odot} \right)^2 \left(\frac{R}{R_\odot} \right)^{-1} \left(\frac{L}{L_\odot} \right)^{-1} \text{years}$$

Determine the constants a and b, and then calculate the free-fall and Kelvin-Helmholtz (where appropriate) timescales for the Earth, Jupiter, a brown dwarf, the Sun, a blue giant and a white dwarf. You may use the table below.

Object	$M/M_\odot$	$R/R_\odot$	$L/L_\odot$
Earth	3.0×10^{-6}	9.2×10^{-3}	—
Jupiter	9.6×10^{-4}	0.103	1.03×10^{-9}
Brown Dwarf	0.1	0.2	1.0×10^{-3}
Sun	1.0	1.0	1.0
Blue Giant	20	6	3×10^4
White Dwarf	0.6	0.01	0.01

Q4. Plot the variation of temperature with mass in a model of the Sun. The data are on the WWW page for this subject:
      `http://users.monash.edu.au/~johnl/astro/ASP3012/stars.html`
      You can use any plotting routine you like. In an emergency you can use *excel*, but you should start using something more scientific! You are urged to start using the very versatile and free linux program called *gnuplot*. Your tutor will show you how. Indeed, in the datafiles I have added a '#' to the start of the lines without data in them as this is the indication to gnuplot that the following line is not to be plotted. You will have to change this (using your favourite editor) if you want to use something other than *gnuplot.*

Q5. Plot an observed Hertzsprung-Russel diagram. The data are again found on the WWW page for this subject (see Q4). You can plot an observers version (M_V or M_{bol} vs. $B - V$) and the theorists version ($\log(L/L_\odot)$ vs. $\log T_e$).

Q6. Also on the WWW page, you will find a data file which contains much more information for a detailed model of the Sun. It contains the temperature, pressure, density, luminosity and compositions as a function of both radius and mass. Plot all of these quantities.
JCL: 10-September-2011