ASTR 321-Fall 2009
Problem set #1

Due Thursday Oct 8 **(problems related to power & lifetime of the Sun)**

Please show all work in as complete, neat, organized and concise a manner as possible

1) Using your hand and knowing that the Sun is 150,000,000 km away (~ the **Astronomical Unit or AU)** you can estimate the Sun's power generation. If you face your hand towards a 100 watt light bulb, 7.5 cm from its center, you will feel the same heat sensation that you feel when your hand is pointed towards the Sun on a clear day. Assume that your hand is a perfect total energy flux sensor and estimate the Sun's total energy generation rate (called the "solar luminosity" $\equiv L_\odot$) **in watts**. Knowing that you generate about 100 watts of power, how much more luminous ($\equiv L_{you}/L_\odot$) you would be than the Sun if you were as massive as the Sun and still generated energy at your present watts/Kg?

2) If the Sun is a sphere with an angular diameter of exactly 0.5 degrees as viewed from Earth, calculate the surface temperature T that is required for it to radiate the power that you determined in question #1. For this problem, determine the Sun's diameter from its angular size and assume that the Sun is a perfect black body that radiates power per unit area from its entire spherical surface at a rate of σT^4 (where σ is the Stephan Boltzman constant – see page 41). (**answer in degrees k**).

3) Estimate how long the Sun can generate this power knowing that the mass of 4 protons that effectively fuse to form a He nucleus in the core of the Sun is 1.008 times the mass of a helium nucleus. The missing mass is converted to energy and this is the Sun's source of energy. Nuclear fusion only occurs in the Sun's hot core- so assume that only 10% of the Sun's mass ever gets hot enough to fuse H into He and that 90% of the Sun's hydrogen does not undergo nuclear reactions. Assume that the Sun starts off as pure hydrogen (almost true) and that the Sun's luminosity is constant during its fusion lifetime (also called its main "sequence lifetime") when it burns hydrogen into helium. (**answer in years**). What is the mass loss rate of the Sun in Kg/s? (note- this is the mass lost not the mass "burned")

4) The lifetime of a star like the Sun is limited by the amount of "burnable" fuel and the rate at which it burns it. The active lifetime is proportional to its mass to luminosity ratio (M/L). For main sequence stars like the Sun, $M/L \propto M^{-2.8}$. Use your answer from question #3 and estimate how massive the Sun would have to be to have already generated all essentially all of its energy (*burned* ~10% of its hydrogen) by its current age of 4.5 billion years. (**answer in solar masses**)

5) If the Sun did not generate power by nuclear fusion, its only energy would be the energy of its collapse from a large low density cloud of material to its present condition as a relatively compact sphere. If this was the sole source of its energy, how long could the Sun put out power at its present rate? **(answer in years)**
Assume that the Sun is a uniform density sphere (a crude approximation because it is much denser in its core) and that the total energy available is the energy available as it collapsed from a sphere of nearly infinite size to its present size.

$$U=\frac{3}{5}\frac{GM_\odot^2}{R}$$

U= gravitational potential energy of a uniform density sphere -- the energy to expand from R to ∞

R = radius, $M_\odot$ = mass of Sun, G= gravitational constant