Workshop 4

1. Approximate the pressure gradient in the Sun as

$$\frac{dP}{dr} \approx -\frac{P_c}{R_\odot}$$

and use the hydrostatic equilibrium equation to estimate crudely the central pressure, P_c, of the Sun. For the density use an average density for the whole Sun.
Then use the ideal gas equation of state:

$$P = \frac{\rho R T}{\mu}$$

where R is the universal gas constant and μ is the mean molar mass, which can be taken to be 0.5 x 10^{-3} kg mol^{-1}, to estimate the central temperature, T_c, at this pressure and average density.

2. We can define a mean free path for photons as below:

- From the definition of opacity

$$dI_\nu = -\kappa_\nu I_\nu ds$$

$$I_\nu(s_2) = I_\nu(s_1)e^{-\kappa_\nu(s_2 - s_1)} \qquad (s_2 > s_1)$$

$$= I_\nu(s_1)e^{-\frac{\Delta s}{\lambda_p(\nu)}}$$

where $\lambda_p(\nu)$ is the distance over which the intensity has dropped significantly (e^{-1}) and is called the mean free path for photons.

$$\lambda_p(\nu) = \frac{1}{\kappa_\nu}$$

The average opacity for the solar interior is about 100 m^{-1}. Hence evaluate the average mean free path for a photon in the Sun. These photons execute a 'random walk' as they are absorbed and re-emitted about 10^{-8} seconds later. Statistics tells us that for N transitions the photon will on average have travelled a distance $N^{1/2}\lambda_p$. Estimate how many transitions a photon will undergo during its passage from the centre to the surface of the Sun. How long will this take? Compare with the light travel time for the same distance.