ASTRONOMY 020

Problem Set #12

Due: January 16, 2004

1. In a one-dimensional random walk process, the average position after N random steps, $\langle x_N \rangle$, is exactly zero, since displacements can occur in either direction with equal probability. However, a photon escaping from a star need only travel a certain distance irrespective of direction. In this case, the important quantity is the expected *square* of the position $\langle x_N^2 \rangle$. It turns out that

$$\langle x_N^2 \rangle = N \, \ell_{\rm mfp}^2, \tag{1}$$

where $\ell_{\rm mfp}$ is the mean free path of the particle/photon. For a three-dimensional random walk, the appropriate expression for mean square radial distance is

$$\langle r_N^2 \rangle = \frac{1}{3} N \, \ell_{\rm mfp}^2. \tag{2}$$

(a) Use the prior discussion to derive the expression

$$t = \frac{3 R_\odot^2}{\ell_{\rm mfp} c} \tag{3}$$

for the escape time of a photon starting a random walk at the center of the Sun.
(b) An average value for the opacity in the Sun is $\kappa = 0.14$ m^2 kg^{-1}. Use this and the mean density of the Sun to estimate the escape time of a photon from the center of the Sun. Give your answer in years.

2. Describe in one or two sentences the following features of the Sun:
(a) photosphere
(b) granulation
(c) corona
(d) solar flare
(e) solar cycle

3. Zeilik & Gregory, Chapter 10, problem 17.

Practice problems:

1. Use the quoted values of the solar radius and luminosity to estimate the surface temperature of the Sun.
Answer: $T \simeq 5770$ K.

2. Zeilik & Gregory, Chapter 10, problem 11.
Using numbers in Table 10-1 and Figure 10-1, $P_{\rm mag} = 3.6 \times 10^4$ Pa and $P_{\rm kin} = 2.0 \times 10^4$ Pa. Magnetic pressure will have a significant effect on local convective motions.