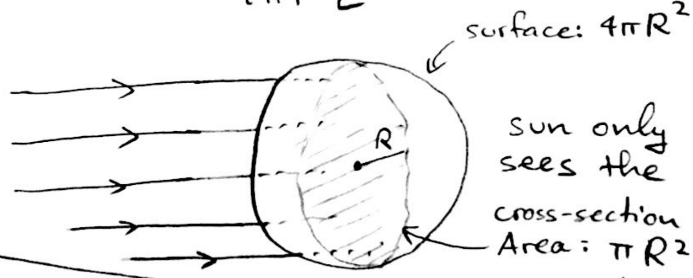
Name: 1C Discussion- Week 6

1. **Radiation Pressure** *(YF 12th ed. 32.55)*. — Interplanetary space contains dust. Radiation pressure from the sun sets a lower limit on the size of such dust particles.
(a) Write down F_G on a particle of mass m a distance r from the sun (mass $M_\odot$).
(b) Let L be the luminosity of the sun, i.e. the rate at which it emits energy. Find the force exerted on the totally absorbing particle.
(c) The mass density of a typical interplanetary dust particle is about $3000 kg/m^3$ and the luminosity is $L = 3.9 \times 10^{26} W$. Find the particle radius R such that the gravitational and radiation forces acting on the particle are equal in magnitude.

a) $$F_G = \frac{G m M_\odot}{r^2}$$

b) $F_{rad} = ?$; $$P_{rad} = \frac{F_{rad}}{A} = \frac{I(r)}{c} = \frac{L}{4\pi r^2 c}$$

$$\Rightarrow F_{rad} = \frac{L \pi R^2}{4\pi r^2 c}$$



c) At equilibrium,

$$F_G = F_{rad}$$

$F_G \leftarrow \ominus \rightarrow F_{rad}$

$$\frac{G m M_\odot}{\cancel{r^2}} = \frac{L \pi R^2}{4\pi \cancel{r^2} c} \quad ; \text{ where } m = \rho_m V = \rho_m \tfrac{4}{3}\pi R^3$$

$$G M_\odot \tfrac{4}{3}\cancel{\pi} R^3 = \frac{L \cancel{\pi} R^2}{4\pi c}$$

$$R_0 = \frac{3L}{G M_\odot 16\pi c} = 0.19\,\mu m$$

Since $F_G \propto R^3$, $F_{rad} \propto R^2$, the gravitational force dominates for $R > R_0$ (earth does not get blown away) and the radiation dominates for $R < R_0$ (no microdust)

2. **Photon**. A 100W lightbulb emits light at an average frequency of $f_m = 1MHz$. Calculate the number of photons per second passing through your pupil ($r = 0.5cm$) at a distance of $100m$. How far would the lightbulb have to be for a flux of one photon per second?

a) $L = 100\,W = \frac{N h f}{1\,\text{second}}$

$I = \frac{L}{4\pi r^2}$

$L_{pupil} = I \cdot A_{pupil} = \frac{L \pi R^2}{4 \pi r^2} = \frac{n h f}{1\,\text{second}}$

$\Rightarrow \frac{n}{1s} = \frac{IA}{hf} = \frac{LR^2}{4r^2 hf} = \frac{100 \cdot 25 \times 10^{-6}}{4 \cdot 100^2 \cdot 6.63 \times 10^{-34} \cdot 10^6} \frac{\text{photon}}{\text{seconds}}$

$= 0.9 \cdot 10^{20}$ photons/sec

b) $\frac{n}{1s} = 1 = \frac{LR^2}{4r^2 hf}$

$\Rightarrow r^2 = \frac{LR^2}{4hf} = 0.9 \cdot 10^{24}\ m^2$

$r = 9.5 \times 10^{11}\,m$

$= 6$ AU

AU: distance from sun to earth.