

## Physics 56400 Assignment #1 – Due September 7<sup>th</sup>

1. High energy electrons or photons propagating through matter are attenuated according to

$$dN = -\frac{N(x)}{X} dx$$

where  $X$  has units of length. The *radiation length*,  $X_0$ , is defined

$$X_0 = \rho X$$

and has dimensions of mass per unit area (*eg.* g/cm<sup>2</sup>).

Use the data in the Particle Data Book to compare the nuclear interaction length,  $\lambda_I$ , and the radiation length,  $X_0$ , for various suitably chosen elements as a function of atomic number. If you plot this with a logarithmic x- and y-axes, show that the slopes of the two relations are different and conclude that the physical processes responsible for the interactions of electrons and photons, and nuclear-type particles, must be different.

2. Show that the number of interaction lengths of a mixture of  $N$  elements with fractional masses  $w_1, w_2, \dots, w_N$  is given by

$$\frac{1}{\lambda_I} = \sum_j w_j \cdot \frac{1}{\lambda_{Ij}}$$

where  $\lambda_{Ij}$  is the nuclear interaction length of element  $j$ . You will probably have to clearly explain how you define the “average cross section” of this mixture of materials and relate it to the cross sections of the individual elements.

3. Suppose a beam of protons has a Gaussian distribution of intensity of the form

$$I(r) = I_0 \frac{1}{2\pi\sigma^2} e^{-r^2/2\sigma^2}$$

where  $I_0 = 10^6 \text{ s}^{-1}$  and  $\sigma = 1 \text{ mm}$ .

Suppose this beam were incident at right-angles to a long, thin wire made of Tungsten, that had a diameter of 100  $\mu\text{m}$ . Using the hard-sphere scattering model, which assumes the beam particles are point-like, calculate the rate at which beam particles are scattered backwards, *i.e.*, at angles  $\theta > \pi/2$  with respect to the beam direction, as a function of the radius of the target Tungsten nuclei. What is this rate, given that Tungsten has a radius of 4 fm?

Any integrals that are difficult to perform analytically should be performed numerically. Just explain how you did them.