Modern Physics 330: HW # 11

1. For a 10 MeV alpha particle, what is the speed v? Calculate the de Broglie wavelength in fm ($\hbar c = 1240$ MeV $\cdot$ fm)

2. For a 10 MeV alpha particle scattering of of a Gold atom with an angle of 10° calculate the corresponding impact paramter b in units of the Bohr radius.

3. For a 10 MeV alpha particle scattering of of a Gold atom, calculate the total cross section for scattering angles $\theta > \theta_{min} = 10°$ in barns. Using the fact that θ_{min} is small, show that $\sigma(\theta > \theta_{min}) = \pi b_{max}^2$, where b_{max} is the impact parameter corresponding to θ_{min}.

4. Calculate the momentum transfer $q = \left|\vec{p} - \vec{p'}\right|$ for 27.5 MeV alpha particle scattering at an angle of 60° where the observed cross section deviates from the Rutherford formula corresponding to a point nucleus (see lecture 17 page 10). Assuming a deviation from point scattering by a factor of 1/4, use the form factor given in the lecture to calculate the corresponding size of the nucleus in fm. Compare your result to the corresponding "hard sphere" nuclear size of the gold nucleus, r = (1.2 fm)$A^{1/3}$.

   The point cross section gets modified by the form factor squared

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_{point}}{d\Omega} F^2$$

   A simple form factor is

$$F(q) = \frac{1}{1 + \frac{qr_0}{\hbar c}}$$

   where r_0 *is the size of the nucleus and* q *is the momentum transfer.*

5. Assume that the entire output of the sun's power 4×10^{26}W comes from the gravitational self energy (refer to lec. 16). Calculate the rate at which the sun's radius would decrease and then calculate the radius as a function of time, R(t). How long would it take for the sun's radius to decrease by 10%? Compare to the age of the sun.

6. Solar fusion

   (a) occurs through the net reaction,

   $$4\mathrm{p} \rightarrow \alpha + 2(\mathrm{e}^{+} + \nu_{\mathrm{e}}) + 3\gamma$$

   The positrons annihilate and contributes to the total energy released. What is the energy released by this fusion process? ($\mathrm{m_p} =$ 938.3 MeV and the atomic mass unit u = 931.5 MeV)

   (b) Calculate the time it would take for all of the protons in the sun to be converted into helium. A small fraction ($< 5\%$) of the energy is carried by neutrinos, so you can assume all the fusion energy goes to energy radiated electromagnetically.

7. Calculate the neutrino flux (number/m^2/s) at the earth's surface coming from the sun.