Nuclear Physics
Homework 2

Instructions. Solve each problem ***carefully*** and ***explain your procedure***.

1. Kinematics of electromagnetic scattering
An electron beam with energy E_e is elastically scattered off a heavy nucleus.
a) Calculate the maximal momentum transfer.
b) Calculate the momentum and energy of the backwardly scattered nucleus in this case.
c) Obtain the same quantities for the elastic scattering of photons with the same energy (nuclear Compton effect).

2. Wavelength
Fraunhofer diffraction upon a circular disc with diameter D produces a ring shaped diffraction pattern. The first minimum appears at $\theta = 1.22\lambda/D$. Calculate the angular separation of the diffraction minima of α particles with energy $E_{kin} = 100\ MeV$ scattered off a ^{56}Fe nucleus. The nucleus should be considered as an impenetrable disc.

3. Rutherford scattering
α particles with $E_{kin} = 6\ MeV$ from a radioactive source are scattered off ^{197}Au nuclei. At which scattering angle are deviations from the cross-section:

$$\left(\frac{d\sigma}{d\Omega}\right)_{Rutherford} = \frac{(zZe^2)^2}{(4\pi\epsilon_0)^2 \cdot (4E_{kin})^2 \cdot sin^4(\frac{\theta}{2})}$$

to be expected?

4. Form factor
Instead of α particles with $E_{kin} = 6\ MeV$ we now consider the scattering of electrons with the same de Broglie wavelength off gold. How large must the kinetic energy of the electrons be? How many maxima and minima will be visible in the angular distribution (cf. Fig. 5.7 from Particles and Nuclei, Povh et. al.)? Since the recoil is small in this case, we may assume that the kinematical quantities are the same in both the centre of mass and laboratory frames.

5. Elastic scattering of X-rays
X-rays are scattered off liquid helium. Which charge carriers in the helium atom are responsible for the scattering? Which of the form factors of Fig. 5.6 (Particles and Nuclei, Povh et. al.) corresponds to this scattering off helium?

6. Compton scattering
Compton scattering off bound electrons can be understood in analogy to quasielastic and deep inelastic scattering. Gamma rays from positronium annihilation are scattered off helium atoms (binding energy of the "first" electron: 24 eV). Calculate the angular spread of the Compton electrons that are measured in coincidence with photons that are scattered by $\theta_\gamma = 30°$.

7. Electron radius
Suppose one wants to obtain an upper bound for the electron's radius by looking for a deviation from the Mott cross-section in electron-electron scattering. What centre of mass energy would be necessary to set an upper limit on the radius of $10^{-3}\ fm$?

8. Electron-pion scattering
State the differential cross-section, $d\sigma/d\Omega$, for elastic electron-pion scattering. Write out explicitly the Q^2 dependence of the form factor part of the cross-section in the limit $Q^2 \to 0$ assuming that $< r^2 >_\pi = 0.44\ fm^2$.