# NPRE 441 Spring 2023
# Quiz 2
(02-27-23)

Your Name: _____

**Question 1: Compton scattering of photons (25 points)**

The Klein-Nishina equation below describes the differential cross section of an electron for Compton scattering.

$$\frac{d\sigma}{d\Omega}(\theta) = r_e^2 \left(\frac{1}{1+\alpha(1-\cos\theta)}\right)^2 \left(\frac{1+\cos^2\theta}{2}\right)\left(1+\frac{\alpha^2(1-\cos\theta)^2}{(1+\cos^2\theta)[1+\alpha(1-\cos\theta)]}\right) \quad (m^2 sr^{-1})$$

$$,where\ \alpha = \frac{h\nu}{m_0 c^2} \quad \text{and} \quad r_e = \frac{k_0 e^2}{m_0 c^2} \text{ is the classic electron radius } (2.818 \times 10^{-15} \text{ m})$$

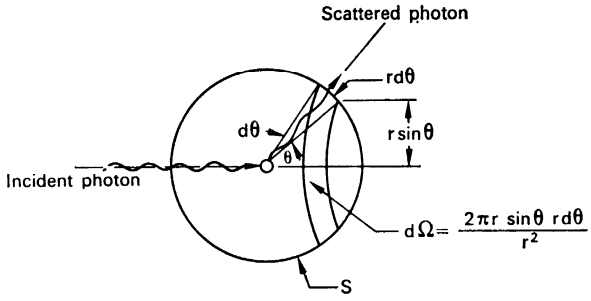
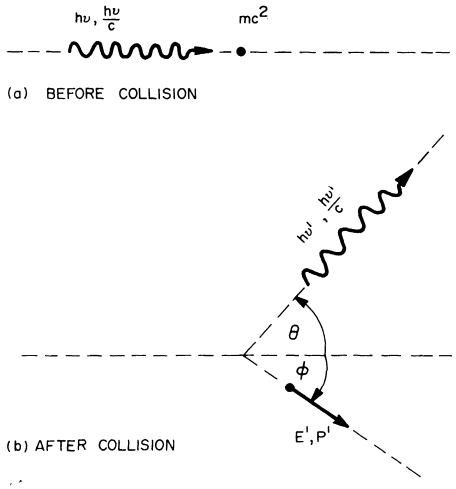



FIG. 5.15. Compton scattering diagram to illustrate differential scattering cross section. *S* is a sphere of unit radius whose center is the scattering electron.

For a gamma ray that undergoes a Compton scattering, the energy carried by the scattered gamma ray is given by the equation below.

$$h\nu' = \frac{h\nu}{1+\frac{h\nu}{mc^2}(1-\cos\theta)}$$



Please write down the equations for evaluating **the average energy transfer from the incident gamma-ray to the recoil electron through a single Compton scattering**.

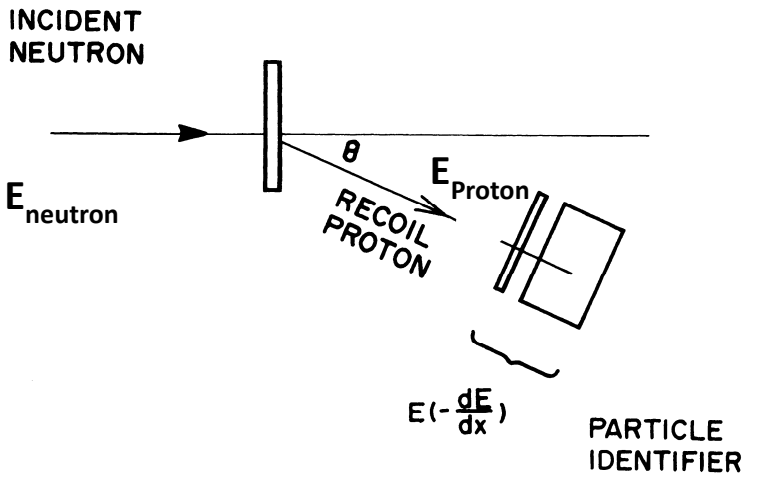
**Question 2: A few conceptual questions (25 points)**

**(A)** What is the so-called **restricted stopping power** for heavy charged particles in a given absorbing media?

**(B)** What is the **energy transfer coefficient**? and what is the **energy absorption coefficient**? Please write down the equations for these attenuation coefficients for X-rays and gamma-rays and explain the meaning of each individual term in the equations.

**Question3: Elastic scattering of fast neutrons (25 points)**

A proton-neutron telescope illustrated below can be used to accurately measure the spectrum of neutrons in a collimated beam. Considering an incident neutron carries a kinetic energy $E_{neutron}$ scattered with a proton, **could you derive the kinetic energy of the recoil proton as a function of the recoil angle $\theta$**?




Arrangement of proton-recoil telescope for measuring spectrum neutron beam.

**Question 4: Neutron Activation Analysis (25 points)**

Considering an object containing $n=10^{22}$ $^{23}$Na atoms. The object is irradiated by a constant thermal neutrons flux, $\phi$=5000 n/cm$^2$/$s$. The neutrons can potentially be captured by $^{23}$Na atoms and induce the following reaction

$$ {}_{0}^{1}n + {}_{11}^{23}Na \rightarrow {}_{11}^{24}Na + {}_{0}^{0}\gamma $$

The cross-section of $^{23}$Na for thermal neutron is 0.534 barns. $^{24}$Na is subject to radioactive decay with the emission of two gamma rays of energies of 2.75 MeV and 1.37 MeV per disintegration. The half-life of $^{24}$Na is roughly 15 hours. **Please derive the number of $^{24}$Na atoms in the object as a function of time**.