6. (10 points)

An incident gamma ray photon of wavelength $1.400 \times 10^{-14}$ m is scattered off a stationary nucleus. The shift in wavelength of the photon is measured for various scattering angles, and the results are plotted on the graph shown below.

(a) On the graph, sketch a best-fit curve to the data.
In one of the trials, the photon is scattered at an angle of 120° with its original direction.

(b) Calculate the wavelength of this photon after it is scattered off the nucleus.

On the graph, the wavelength that corresponds to 120° of scattering angle is approximately \(8 \times 10^{-17} \text{m}\).

\[
\lambda = 1.4 \times 10^{-14} \text{m} + 8 \times 10^{-17} \text{m} = 1.408 \times 10^{-14} \text{m}
\]

(c) Calculate the momentum of this scattered photon.

\[
P = \frac{\hbar}{\lambda} = \frac{6.63 \times 10^{-34} \text{J} \cdot \text{s}}{1.408 \times 10^{-14} \text{m}} = 4.709 \times 10^{-20} \text{N} \cdot \text{s}
\]

(d) Calculate the energy that this scattering event imparts to the recoiling nucleus.

The frequency of the incident gamma ray photon \(f_0\) is

\[
f_0 = \frac{v}{\lambda} = \frac{3 \times 10^8 \text{m/s}}{1.4 \times 10^{-14} \text{m}} = 2.14 \times 10^{22} \text{Hz}
\]

The original energy of the photon is then,

\[
E_0 = h f_0 = 6.63 \times 10^{-34} \text{J} \cdot \text{s} \cdot 2.14 \times 10^{22} \text{Hz} = 1.421 \times 10^{-11} \text{J}
\]

The energy of the scattered photon is

\[
E_i = h f_i = \frac{h v}{\lambda_i} = 6.63 \times 10^{-34} \text{J} \cdot \text{s} \cdot 3 \times 10^8 \text{m/s} / (1.408 \times 10^{-14} \text{m}) = 1.413 \times 10^{-11} \text{J}
\]

The energy imparted is

\[
E_i - E_f = 8 \times 10^{-15} \text{J}
\]
6. (10 points)

An incident gamma ray photon of wavelength $1.400 \times 10^{-14}$ m is scattered off a stationary nucleus. The shift in wavelength of the photon is measured for various scattering angles, and the results are plotted on the graph shown below.

(a) On the graph, sketch a best-fit curve to the data.
In one of the trials, the photon is scattered at an angle of 120° with its original direction.

(b) Calculate the wavelength of this photon after it is scattered off the nucleus.

\[ \lambda = 1.400 \times 10^{-10} \text{ m} + 8.000 \times 10^{-17} \text{m} \]
\[ = 1.408 \times 10^{-14} \text{m} \]

(c) Calculate the momentum of this scattered photon.

\[ p = \frac{\hbar}{\lambda} \]
\[ = \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{1.408 \times 10^{-14} \text{ m}} \]
\[ = 4.709 \times 10^{-20} \text{ kg} \cdot \text{m/s} \]

(d) \( E = mc^2 \) corresponding to the recoil of the nucleus.

\[ E = (4.709 \times 10^{-20} \text{ kg} \cdot \text{m/s}) (3.00 \times 10^8 \text{ m/s}) \]
\[ = 1.413 \times 10^{-11} \text{ J} \]