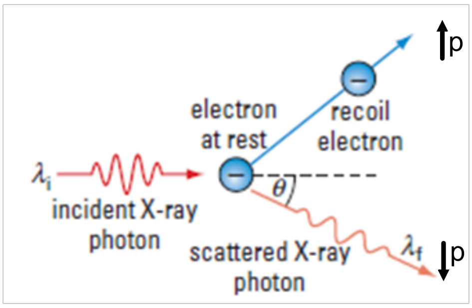
L16 - Compton's Effect - EMR has Momentum



http://www.kcvs.ca/site/projects/physics_files/compton-scattering/compton-scattering.swf *(File might not run in Chrome... try Firefox)*

Momentum of Particles	Momentum of Photon	Energy of Photon
$\vec{p} = m\vec{v}$	$p = \frac{h}{\lambda} = \frac{Js}{m}$ $W = Fd$ $J = Nm$	$E = \frac{hc}{\lambda}$ $E = pc$
Units? $\vec{p} = (kg)(m/s)$ $= kg\,m/s$	Units? $p = \frac{(J)s}{m} = \frac{(Nm)s}{m}$ $\vec{p} = Ns$ Newton seconds	Units? $p = \frac{Js}{m}$ $E = (p)c$ $= \left(\frac{Js}{m}\right)\left(\frac{m}{s}\right)$

Q1: What is the energy of red light 700 nm?

$E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(700\times10^{-9})} = 2.8414...\times10^{-19}\,J$ $= J$

Q2: What is the energy of blue light 450 nm?

$E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(450\times10^{-9})} = 4.42\times10^{-19}\,J$

Q3: What is the momentum of red light?

$p = \frac{h}{\lambda} = \frac{(6.63\times10^{-34})}{700\times10^{-9}} = 9.47\times10^{-28}\,Ns$

or $E = pc$

$2.8414...\times10^{-19} = p(3.0\times10^{8})$

$p = 9.47\times10^{-28}\,Ns$

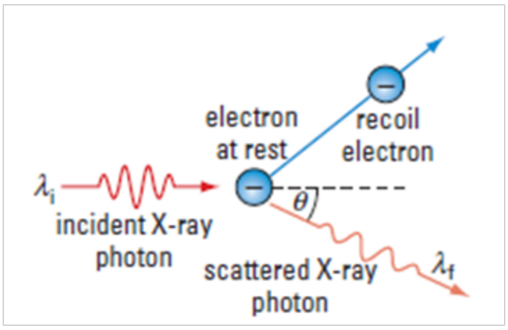
Q4: What is the momentum of blue light?

$E = pc$

$4.42\times10^{-19} = p(3.0\times10^{8})$

$p = 1.47\times10^{-27}\,Ns$

Compton Scattering - Mathy Time!!!



Will wavelength increase or decrease?

$$p = \frac{h}{\lambda}$$

$$\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$$

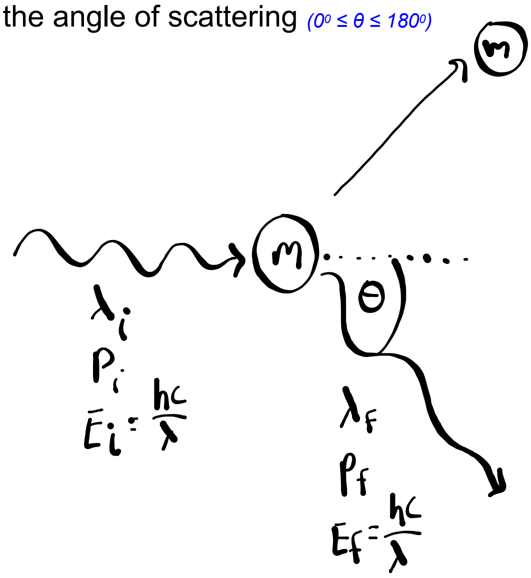
$\Delta\lambda$ → Change in λ Not λ_f

m → Mass of object hit (typically electron)

θ → Scattered photon (not electron)

Variables:

- m is the mass of the scattered particle *($m_e = 9.11 \times 10^{-31}$ kg)*
- c is the speed of light *($c = 3.0 \times 10^{8}$ m/s)*
- θ is the angle of scattering *($0^{\circ} \leq \theta \leq 180^{\circ}$)*



1. Momentum is conserved
2. Collision is elastic (Energy is conserved)

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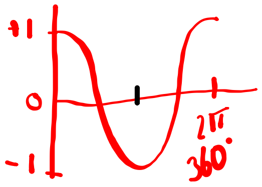
Q1: What is the maximum change in wavelength that a 0.010 nm X-ray photon can undergo by Compton scattering with an electron?

Does the initial wavelength matter in this example?

$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$ Largest when $\theta = 180°$

When is it a max?



$$\Delta\lambda = \frac{(6.63\times10^{-34})}{(9.11\times10^{-31})(3.0\times10^{8})}(1-\cos180°)$$

$\Delta\lambda = 4.8518\times10^{-12}\,m$

Q2: An X-ray photon of wavelength 0.0500 nm scatters at an angle of 30°. Calculate the waveleng of the scattered photon.

$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$

$$\Delta\lambda = \frac{(6.63\times10^{-34})}{(9.11\times10^{-31})(3\times10^{8})}(1-\cos30)$$

$$\Delta\lambda = (2.4259...\times10^{-12})(0.13397...)$$

$= 3.25\times10^{-13}\,m$

$\Delta\lambda = \lambda_f - \lambda_i$

$3.25...\times10^{-13} = \lambda_f - 0.05\times10^{-9}$

$\lambda_f = 5.0325\times10^{-11}\,m$