Photon Interactions

Section 27-4

Compton Effect

$p = mv$

$E = hf$

$E = \frac{hc}{\lambda}$

$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

$E = mc^2$, $E^2 = m^2c^4 + p^2c^2$

$E^2 = m_0^2c^4 + p^2c^2$

$E = pc$

$p_\gamma = m_{eff}c$

$E = m_{eff}c^2$

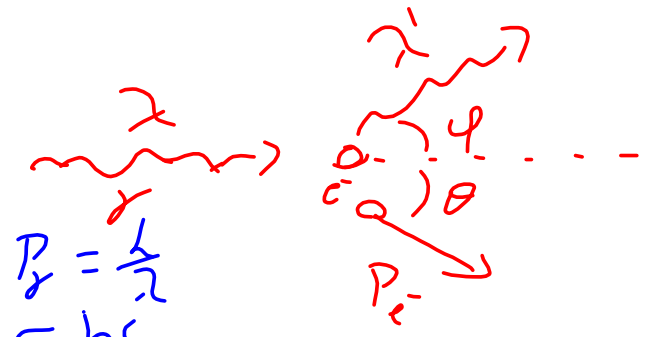
$\frac{hc}{\lambda} = m_{eff}c^2$

$\frac{hc}{\lambda} = p_\gamma c$

$m_{eff} = \frac{h}{\lambda c}$

$p_\gamma = \frac{h}{\lambda}$

The Experiment...



$P_\gamma = \frac{h}{\lambda}$

$E = \frac{hc}{\lambda}$

Conservation P_x

$$P_{\gamma x} + 0 = P'_{\gamma x} + P'_{e^- x} \Rightarrow \frac{h}{\lambda} = \frac{h}{\lambda'}\cos\varphi + p'_{e^-}\cos\theta \quad (1)$$

Conservation P_y

$$0 = P'_{\gamma y} + P'_{e^- y} \Rightarrow \frac{h}{\lambda'}\sin\varphi = p'_{e^-}\sin\theta \quad (2)$$

Conservation of E

$$E_\gamma + E_{e^-} = E'_\gamma + E'_{e^-}$$

$$\frac{hc}{\lambda} + m_{oe^-}c^2 = \frac{hc}{\lambda'} + \sqrt{m_{oe^-}^2 c^4 + p'^2_{e^-} c^2} \quad (3)$$

Let's Derive an Equation!

① $\frac{h}{\lambda} = \frac{h}{\lambda'}\cos\varphi + p_e' \cos\theta$

② $\frac{h}{\lambda'}\sin\varphi = p_e' \sin\theta$

③ $\frac{hc}{\lambda} + m_{oe}c^2 = \frac{hc}{\lambda'} + \sqrt{p_e^2 c^2 + m_{oe}^2 c^4}$

① $p_e'^2 \cos^2\theta = \frac{h^2}{\lambda^2} - \frac{2h^2}{\lambda\lambda'}\cos\varphi + \frac{h^2}{\lambda'^2}\cos^2\varphi$

② $p_e'^2 \sin^2\theta = \frac{h^2}{\lambda'^2}\sin^2\varphi$

$p_e'^2(\sin^2\theta + \cos^2\theta) = \frac{h^2}{\lambda^2} - \frac{2h^2}{\lambda\lambda'}\cos\varphi + \frac{h^2}{\lambda'^2}(\sin^2\varphi + \cos^2\varphi)$

$\Rightarrow p_e'^2 = \frac{h^2}{\lambda^2} - \frac{2h^2}{\lambda\lambda'}\cos\varphi + \frac{h^2}{\lambda'^2}$ (4)

$\frac{hc}{\lambda} + m_{oe}c^2 = \frac{hc}{\lambda'} + \sqrt{\left(\frac{h^2}{\lambda^2} - \frac{2h^2}{\lambda\lambda'}\cos\varphi + \frac{h^2}{\lambda'^2}\right)c^2} + \sqrt{m_{oe}^2 c^4}$

$\left[\left(\frac{hc}{\lambda} - \frac{hc}{\lambda'}\right) + m_{oe}c^2\right]^2 = \left(\frac{h^2}{\lambda^2} - \frac{2h^2}{\lambda\lambda'}\cos\varphi + \left(\frac{h}{\lambda'}\right)^2\right)c^2 + m_{oe}^2 c^4$

$\left(\frac{hc}{\lambda} - \frac{hc}{\lambda'}\right)^2 + 2m_{oe}c^2\left(\frac{hc}{\lambda} - \frac{hc}{\lambda'}\right) + m_{oe}^2 c^4 = \left(\frac{hc}{\lambda}\right)^2 - \frac{2h^2c^2}{\lambda\lambda'}\cos\varphi + \left(\frac{hc}{\lambda'}\right)^2 + m_{oe}^2 c^4$

$\left(\frac{hc}{\lambda}\right)^2 - \frac{2h^2c^2}{\lambda\lambda'} + \left(\frac{hc}{\lambda'}\right)^2 + 2m_{oe}c^3 h\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \left(\frac{hc}{\lambda}\right)^2 - \frac{2h^2c^2}{\lambda\lambda'}\cos\varphi + \left(\frac{hc}{\lambda'}\right)^2$

$-\frac{2h^2c^2}{\lambda\lambda'} + 2m_{oe}c^3 h\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = -\frac{2h^2c^2}{\lambda\lambda'}\cos\varphi$

$2m_{oe}c^3 h\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \frac{2h^2c^2}{\lambda\lambda'}(1 - \cos\varphi)$

$\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \frac{h}{m_{oe}\lambda\lambda' c}(1 - \cos\varphi)$

$\lambda' - \lambda = \frac{h}{m_{oe}c}(1 - \cos\varphi)$

$$\boxed{\lambda' = \lambda + \frac{h}{m_{oe}c}(1 - \cos\varphi)}$$

Photon Interactions

1. Scattered off a particle - Compton Effect

2. Absorption with displacement of electron - Photoelectric Effect

3. Absorption causing atom excitation

4. Pair production

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

$mv = \frac{h}{\lambda}$ $\quad \lambda = \frac{h}{mv}$

4) De Broglie Wavelength