# Physics 262 Exam 3 Solutions.

(1.) $e^- \longrightarrow$

a.) $p = mv = \frac{h}{\lambda}$

$$\frac{v}{c} = \frac{h}{mc\lambda} = \frac{hc}{mc^2\lambda} = \frac{1240 \text{ eV nm}}{(0.511 \times 10^6 \text{ eV})(0.1 \text{ nm})} \sim 0.02$$

b.) $$E = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2} = \frac{(hc)^2}{2(mc^2)\lambda^2} = \frac{(1240 \text{ eV nm})^2}{2(0.511 \times 10^6 \text{ eV})(0.1 \text{ nm})^2}$$

$$\sim \frac{(10^6 \text{ eV}^2 \text{nm}^2)}{(10^6 \text{ eV})(10^{-2} \text{ nm}^2)} = 100 \text{ eV}$$

$V = 100$ V

c.)

All electron Kinetic Energy goes to creating a photon

$E = \frac{hc}{\lambda}$ (photon)

$\lambda = \frac{hc}{E}$ using electron Energy

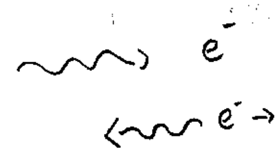
$$\lambda = \frac{(hc)(2m\lambda^2)}{h^2} = \frac{(hc)\, 2mc^2\lambda^2}{(hc)^2} = \frac{2mc^2\lambda^2}{hc}$$

$$= \frac{2(0.511 \times 10^6 \text{ eV})(0.1 \text{ nm})^2}{(1240 \text{ eV} \cdot \text{nm})} \sim 10 \text{ nm}$$

(2.) $E = 100\ eV$

a.) $E = pc$

$$p = \frac{E}{c} = \frac{100\ eV}{3\times10^{8}\ m/s} \times \frac{1.6\times10^{-19}\ J}{eV} \sim 5\times10^{-26}\ kg\ m/s$$



b.) Compton Scattering

$$\lambda_f - \lambda_i = \frac{h}{m_e c}(1-\cos\theta)$$

$\theta = \pi$

$p = \frac{h}{\lambda}$ $\qquad E = \frac{hc}{\lambda}$

$$\lambda_f - \lambda_i = \frac{2h}{mc}$$

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

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

$$\lambda_f = \frac{2h}{mc} + \frac{hc}{E} = \frac{2hE + hmc^2}{mcE}$$

$$p_f = \frac{h}{\lambda_f} = \frac{mcE}{2E - mc^2} = \frac{E/c}{\underbrace{2E/mc^2}_{\text{small}} + 1}$$

$p_f \sim p_i$ or $\vec{p}_f \sim -\vec{p}_i$

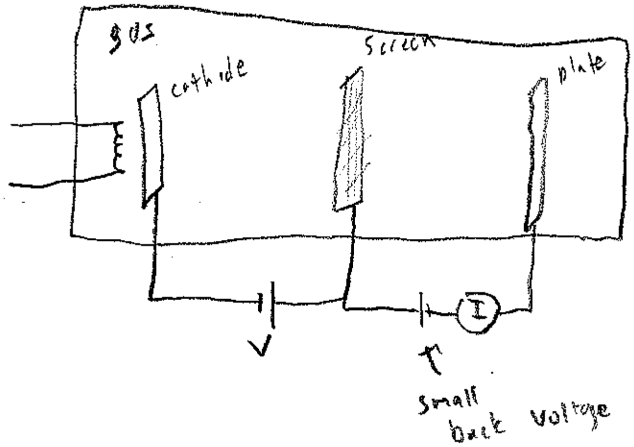
c.) $\Delta\vec{p}_\lambda = \vec{p}_f - \vec{p}_i = \left[-\frac{E/c}{2E/mc^2 + 1} - E/c\right]$ ↑ change in photon momentum by equal change in electron momentum

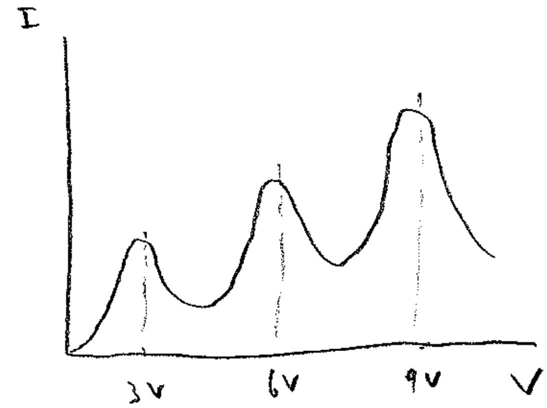
photon

$$\Delta p_\lambda \simeq -E/c\left(1 - 2E/mc^2\right) - E/c = -\frac{2E}{c} + \frac{2E}{m_e c^2}$$

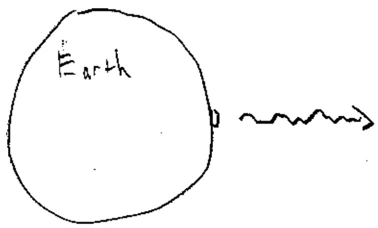
$$|\Delta p_e| = |\Delta p_\lambda| = \frac{2E}{c} - \underbrace{\frac{2E}{m_e c^2}}_{\text{small}} \approx 2\frac{E}{c} = 2p_i$$

3.




4.




The light will have a gravitational Redshift, meaning a longer wavelength will be observed in space.

s: space
E: earth

$$\frac{\lambda_s}{\lambda_E} = \frac{\nu_E}{\nu_s} = \frac{d\tau_s}{d\tau_E} = 1 + \frac{\cancel{\Phi_s}^{\,0}}{c^2} - \frac{\Phi_E}{c^2} = 1 + \frac{GM}{r_E c^2} \leftarrow \text{always} > 1$$

so $\frac{\lambda_s}{\lambda_E} > 1$

where $r_E$ is radius of earth

$\Phi_s \to 0$ as $r \to \infty$