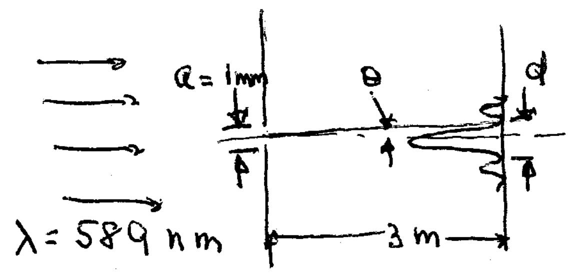
Problem #1



a) Intensity pattern given by $I = I_0 \dfrac{\sin^2\alpha}{\alpha^2}$

$$\alpha = \frac{\pi a \sin\theta}{\lambda}$$

First diffraction minima occur when $\alpha = \pm\pi$

or $a \sin\theta = \pm\lambda$

Using small ∡ approximation: $\theta = \pm \lambda/a = \pm 5.89\times10^{-4}$ rad.

$\therefore$ d = separation $= 2(5.89\times10^{-4})(300) = \underline{0.35\ cm.}$

b) I) If slit width doubled separation $= d/2 = 0.177$ cm.

II) The electric field (E_0) arriving on screen is $\propto a$.
$\therefore$ If slit width is doubled, the electric field is doubled and $I \propto E_0^2$ will be quadrupled.

c) Condition for second diffraction minimum: $\sin\theta = \dfrac{2\lambda'}{a}$

" " Third " " $\sin\theta = \dfrac{3\lambda}{a}$

$$\therefore \boxed{\lambda' = 3/2\,\lambda = 883.5\,nm.}$$

Problem # 2

a) Use Lorentz transformation:

$$x_1' = \gamma(x_1 - vt_1) = \gamma(0-0) = 0$$

$$x_2' = \gamma(x_2 - vt_2) = \gamma x_2 = \frac{30}{\sqrt{1-\left(\frac{0.5c}{c}\right)^2}} = 34.6\ \text{Km.}$$

$$\therefore \Delta x' = x_1' - x_2' = 34.6\ \text{Km.}$$

b) $$t_1' = \gamma\left(t_1 - \frac{v}{c^2}x_1\right) = \gamma(0-0) = 0$$

$$t_2' = \gamma\left(t_2 - \frac{v}{c^2}x_2\right) = \gamma\left(0 - \frac{0.5c}{c^2}\,30\,\text{km}\right) = -5.77\times10^{-5}\ \text{s.}$$

$$\Delta t = t_1' - t_2' = 5.77\times10^{-5}\ \text{s.}$$

c) white light flashes first.

Problem # 3

According to Compton scattering formula:

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

$$= ,00243(1-\cos\theta) \quad nm.$$

$\lambda' = \cancel{,247}\ \cancel{,00210 + ,0032}$

$\lambda' = ,00243$ nm.

Conservation of energy: $hc/\lambda - \frac{hc}{\lambda'} + \cancel{m_e c^2} = K + \cancel{m_e c^2}$

$$\therefore K = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right)$$

$$= 1.9\times10^{-25}\left(64.67\times10^{9}\right) = 1.23\times10^{-14} \text{ joules}$$

$K = 76.8$ KeV

Problem # 4

$$I_{star} = \sigma T^4 = 5.67 \times 10^{-8} (6600)^4 = 1.08 \times 10^8 \ \mathrm{W/m^2}$$

Total Power radiated $= I \, 4\pi r^2$ (r = radius of star)

F = flux reaching us $= \dfrac{I \, 4\pi r^2}{4\pi R^2}$ R = 11 light years.

$$\therefore \ 1.7 \times 10^{-12} = I \, \frac{r^2}{R^2}$$

$$\text{or} \quad r = R \sqrt{\frac{1.7 \times 10^{-12}}{1.08 \times 10^8}} = 11 (1.26 \times 10^{-10}) = 1.39 \times 10^{-9} \ \text{light years}$$

$$\text{or} \quad r = 1.31 \times 10^4 \ \mathrm{Km}.$$

Problem # 5

5a) $E(\text{photon}) = hf = (4.14 \times 10^{-15})(10^{16}) = 41.4\ eV$

$E(\text{bound electron}) = -\frac{Z^2}{n^2} R_y = -\frac{1}{1}(13.6\ eV) = -13.6\ eV$

$K(\text{emitted electron}) = E(\text{photon}) + E(\text{bound electron})$

$$\boxed{K = 27.8\ eV}$$

5b) If the energy of the recoiling atom is small, the energy of the emitted photon will be:

$$E_f = R_y \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = (13.6)\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$E_f = 1.89\ eV$$

In the above calculation, the energy of the recoiling atom is neglected.
The atom will recoil so that momentum is conserved:

$$P_{atom} = P_f$$

$$\therefore E_{atom} = \frac{P_{atom}^2}{2M} = \frac{P_f^2}{2M}$$

$$P_f = E_f / c$$

$$\therefore E_{atom} = \frac{E_f^2}{2Mc^2} = \frac{(1.89)^2}{2(938 \times 10^6)} = 1.9 \times 10^{-9}\ eV$$