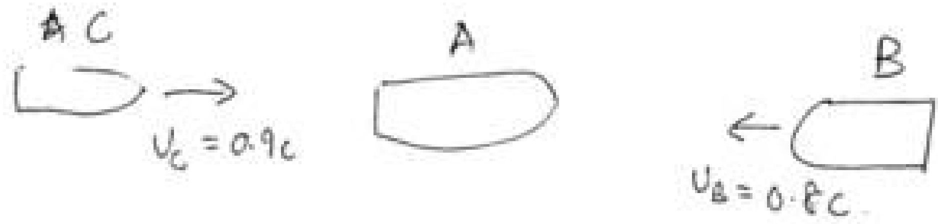
1



→ Assume that the direction to the right-hand side is positif

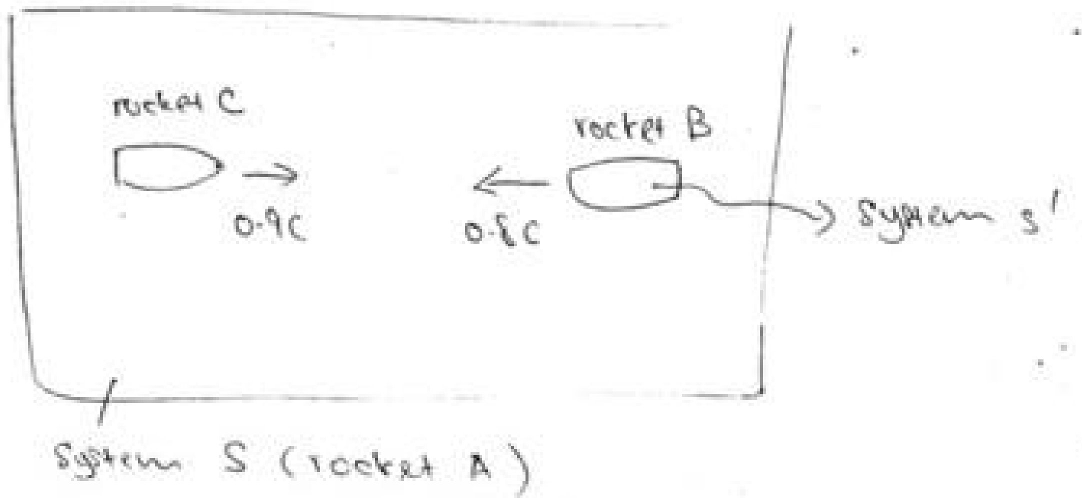
→ With respect to the rocket A,

→ the speed of rocket B, $v_B = -0.8c$

→ the speed of rocket C, $v_C = 0.9c$.

→ the speed of rocket C as measured by B :

→ Now, we may assume that the rocket B is a moving system (system S')



→ Here, $V = -0.8c$, $v_x\ (v_c) = 0.9c$ and we need to determine v_x' (speed of rocket C as measured by B)

1. By Galileo approach.

$$V_x' = V_x - V$$

$$= 0.9c - (-0.8c) = 1.7c$$

By Special relativity approach:

$$V_x' = \frac{V_x - V}{1 - \left(\frac{V}{c^2}\right)V_x}$$

$$= \frac{0.9c - (-0.8c)}{1 - \left(\frac{-0.8c}{c^2}\right)(0.9c)}$$

$$= \frac{1.7c}{1 + 0.72}$$

$$= \frac{1.7}{1.72}c$$

$$= 0.9884c$$

(5) Given that the threshold wavelength (or cut-off wavelength) of the metal is

$$\lambda_{cutoff} = 600 \text{ nm}.$$

→ The work function of this metal is given by

$$W_0 = \frac{hc}{\lambda_{cutoff}} \quad (1)$$

or

$$W_0 = hf_{cutoff} \quad (2)$$

where h = Planck constant

f_{cutoff} = cut-off or threshold frequency $= \frac{c}{\lambda_{cutoff}}$

→ From (1), hence,

$$W_0 = \frac{1240 \text{ eV}\cdot\text{nm}}{600 \text{ nm}} = 2.067 \text{ eV}$$

→ The photoelectric (PE) formula is given by

$$eV_s = hf - W_0 \quad (3)$$

or

$$eV_s = \frac{hc}{\lambda} - W_0 \quad (4)$$

where e = charge of an electron

V_s = stopping potential

or

$K_{max} = eV_s$

i.e. $K_{max} = hf - W_0$.

2 (a) Given that $\lambda = 400nm$.

⇒ ~~From~~ By using Eq. (4).

$$\therefore \quad eV_s = \frac{1240 \text{ eV.nm}}{400} - 2.067 \text{ eV}$$

$$= 3.100 \text{ eV} - 2.067 \text{ eV}$$

$$= 1.033 \text{ eV}$$

$$\therefore \quad V_s = 1.033 \text{ V}$$

2b) Assume that the light frequency ~~of~~ in 2(a) is $f_1 = f = \frac{c}{\lambda}$

Now, the light frequency is, $f_2 = 2f = \frac{2c}{\lambda}$

→ By replacing $f_2 = \frac{2c}{\lambda}$ into Eq. (3), hence.

$$eV_s = \frac{2hc}{\lambda} - W_0$$

$$= 2\left(\frac{1240 \text{ eV.nm}}{400}\right) - 2.067 \text{ eV}$$

$$= 2(3.100 \text{ eV}) - 2.067 \text{ eV}$$

$$= 6.200 \text{ eV} - 2.067 \text{ eV}$$

$$= 4.133 \text{ eV}$$

$$\therefore \quad V_s = 4.133 \text{ V}$$

2(c) → the stopping potential V_s is independent of the ~~light~~ intensity of light.

→ Hence, the V_s remain the same as in 2(a)

$\therefore \quad V_s = 1.033\ V$ //

3.

⇒ The compton shift relationship is given by

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_o c}(1 - \cos\theta) \quad (1)$$

or $$\lambda' - \lambda = \lambda_e (1 - \cos\theta)$$

where
λ = wavelength of the incident photon
λ' = wavelength of the scattered photon.
m_o = rest mass of electron.
θ = angle of the scattered photon.
λ_e = compton wavelength = 2.43×10^{-3} nm.

3 (a) Here, $\lambda = 0.0248$ nm , $\theta = 90°$, $\lambda' = ?$

⇒ From Eq. (1),

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

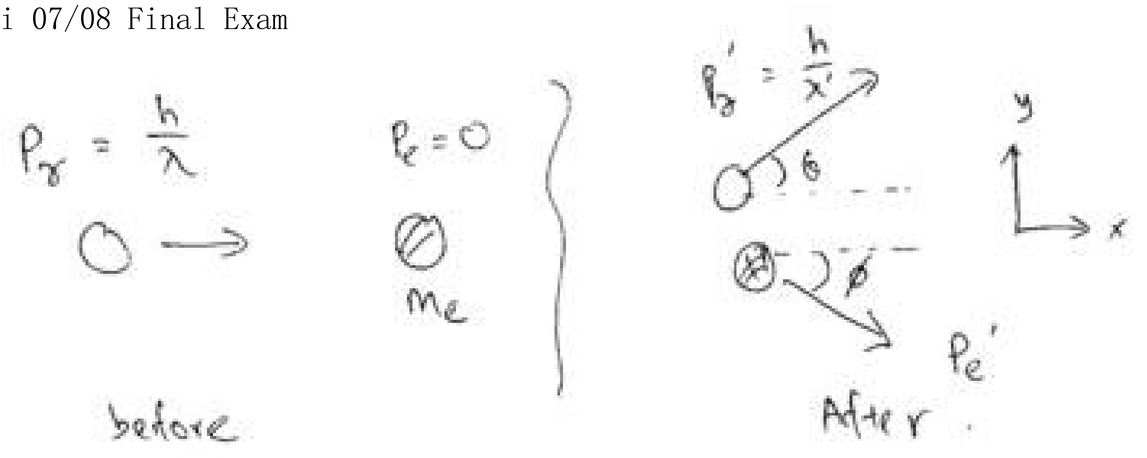
$$\lambda' = 2.43 \times 10^{-3} [1 - \cos(90)] + \lambda$$

$$= 2.43 \times 10^{-3} \text{ nm} + 0.0248 \text{ nm}$$

$$= 0.02723 \text{ nm}$$

$$= 2.723 \times 10^{-2} \text{ nm}$$ #

3 b)



– Momentum of the incident photon

$$P_\gamma = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ \text{Js}}{0.0248\ \text{nm}}$$

$$= \frac{6.63 \times 10^{-34}\ \text{Js}}{2.48 \times 10^{-11}\ \text{m}}$$

$$= 2.673 \times 10^{-23}\ \text{kg ms}^{-1}$$ #

– momentum of the scattered photons.

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

$$= \frac{6.63 \times 10^{-34}\ \text{Js}}{2.723 \times 10^{-2}\ \text{nm}}$$

$$= \frac{6.63 \times 10^{-34}\ \text{Js}}{2.723 \times 10^{-11}\ \text{m}}$$

$$= 2.435 \times 10^{-23}\ \text{kg ms}^{-1}$$ #

Or

$$|P_\gamma'| = \sqrt{(P_\gamma' \sin\theta)^2 + (P_\gamma' \cos\theta)^2}$$

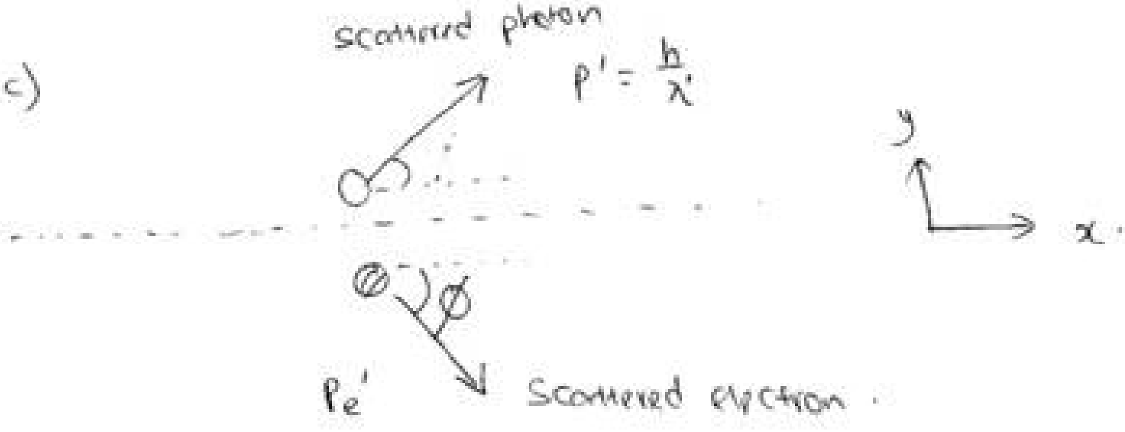
$$= \sqrt{P_\gamma'^2}$$

$$= P_\gamma'$$

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

$$= 2.435 \times 10^{-23}\ \text{kgm}$$

3 c)



After collision

- Use the conservation of linear momentum in x- and y- directions.

Total momentum before = Total momentum after.

$$\therefore \quad p + p_e = p' + p_e' \qquad (1)$$

→ In x- direction

$$p + 0 = p'\cos\theta + p_e'\cos\phi$$

$$\therefore \quad p_e'\cos\phi = p - p'\cos\theta \qquad (2)$$

→ In y- direction

$$0 = p'\sin\theta - p_e'\sin\phi$$

$$\therefore \quad p_e'\sin\phi = p'\sin\theta \qquad (3)$$

3 c) $\frac{③}{②}$ $$\frac{P_e' \sin\phi}{P_e' \cos\phi} = \frac{p' \sin\theta}{p - p' \cos\theta}$$

$$\therefore \tan\phi = \frac{\sin\theta}{p/p' - \cos\theta} \quad ④$$

- magnitude of the momentum of the scattered electron can be calculated using ~~Eq~~ Eq. (1).

$$p = p' + P_e'$$

$$\therefore P_e' = p - p'$$

$$= 2.673 \times 10^{-23} \text{ kg ms}^{-1} - 2.435 \times 10^{-23} \text{ kgms}^{-1}$$

$$= 0.238 \times 10^{-23} \text{ kg ms}^{-1}$$

$$= 2.38 \times 10^{-24} \text{ kg ms}^{-1}$$

→ the direction of the momentum of the scattered electron can be determined by using Eq. ④

$$\therefore \tan\phi = \frac{\sin\theta}{p/p' - \cos\theta}$$

$$= \frac{\sin(90^\circ)}{\left(\frac{2.673 \times 10^{-23}}{2.435 \times 10^{-23}}\right) - \cos(90^\circ)} = \frac{1}{1.0977} = 0.911$$

$$\phi = 42.33^\circ .$$

(4) a)

→ Heisenberg's uncertainty principle is given by

$$\Delta x \, \Delta p \geq \frac{\hbar}{2} \quad \text{where} \quad \hbar = \frac{h}{2\pi}$$

$$\therefore \quad \Delta x \geq \frac{\hbar}{2} \cdot \frac{1}{\Delta p}$$

→ The minimum uncertainty in the position is then

$$\Delta x = \frac{\hbar}{2} \cdot \frac{1}{\Delta p} \qquad (1)$$

→ Given that $m = 46 \text{ gm} = 46 \times 10^{-3}$ kg.

$$v = 2 \text{ ms}^{-1}.$$

→ then, the momentum of the golf ball is

$$p_g = mv = (46 \times 10^{-3} \text{ kg}) \times (2 \text{ ms}^{-1})$$

$$= 9.2 \times 10^{-2} \text{ kg ms}^{-1} \; *$$

→ Given that the accuracy of the momentum = 0.1%

$$\therefore \quad \Delta p_g = 0.1\% \times p_g = \frac{0.1}{100} \times 9.2 \times 10^{-2} \text{ kgms}^{-1}$$

$$= 9.2 \times 10^{-5} \text{ kg m s}^{-1}$$

→ From Eq. (1), then

$$\Delta x = \frac{\hbar}{2} \cdot \frac{1}{\Delta p}$$

$$= \frac{6.63 \times 10^{-34}}{4\pi \, (9.2 \times 10^{-5})} = 5.735 \times 10^{-31} \text{ m.}$$

*

4. a)

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*

4 b) Here, $m_0 = 9.1 \times 10^{-31}$ kg, $V = 2.4 \times 10^{8}$ ms^{-1}.

- In this case, we must treat the problem relativistically, namely,

$$P_e = \gamma m_0 V$$

where $$\gamma = \frac{1}{\sqrt{1-\frac{v}{c}}} = \frac{1}{\sqrt{1-\frac{2.4\times10^{8}}{3.0\times10^{8}}}} = 2.236$$

$$\therefore P_e = 2.236\,(9.1\times10^{-31})(2.4\times10^{8}) = 4.883\times10^{-22}\ \text{kgms}^{-1}$$

→ Given that the uncertainty of momentum = 0.1%

$$\therefore \Delta P_e = 0.1\% \times P_e$$
$$= \frac{0.1}{100} \times 4.883\times10^{-22} = 4.883\times10^{-25}\ \text{kgms}^{-1}$$

→ From Eq (1), then

$$\Delta x = \frac{\hbar}{2} \cdot \frac{1}{\Delta P_e}$$
$$= \frac{6.63\times10^{-34}}{4\pi\,(4.883\times10^{-25})}$$
$$= 1.080\times10^{-10}\ \text{m}.$$

5 a)

→ The Paschen series for hydrogen is given by

$$\frac{1}{\lambda} = R_H \left[\frac{1}{3^2} - \frac{1}{n_i^2} \right] \quad (1)$$

where R_H = Rydberg constant $= 1.097 \times 10^7 \ m^{-1}$

$n_i = 4, 5, 6, \ldots$

→ the longest wavelength of the Paschen series for hydrogen corresponds to

$$n_i = \infty$$

$$\therefore \frac{1}{\lambda} = R_H \left[\frac{1}{3^2} - \frac{1}{\infty^2} \right]$$

$$= 1.097 \times 10^7 \left(\frac{1}{9} - 0 \right)$$

$$= 1.2189 \times 10^6 \ m^{-1}$$

$$\therefore \lambda = 8.204 \times 10^{-7} \ m$$

#

5 b)

→ The shortest wavelength of the Paschen series for hydrogen is corresponds to

$$n_i = n_f + 1$$
$$= 3 + 1$$
$$= 4$$

$$\therefore \quad \frac{1}{\lambda} = R_H \left[\frac{1}{3^2} - \frac{1}{4^2} \right]$$
$$= 1.097 \times 10^{7} \left[\frac{1}{9} - \frac{1}{16} \right]$$
$$= 5.333 \times 10^{5} \ m^{-1}$$

$$\therefore \quad \lambda = 1.875 \times 10^{-6} \ m$$

#

5 b)

→ The general formula of the spectral line series for hydrogen is given by

$$\frac{1}{\lambda} = R_H \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right].$$

→ Given that $\lambda = 4861 \text{ Å} = 4861 \times 10^{-10}$ m

and $n_f = 2$.

→ from 5(a), $R_H = 1.097 \times 10^7 \text{ m}^{-1}$.

$$\therefore \quad \frac{1}{4861 \times 10^{-10}} = 1.097 \times 10^7 \left[\frac{1}{2^2} - \frac{1}{n_i^2} \right].$$

$$\frac{1}{(4861 \times 10^{-10})(1.097 \times 10^7)} = \left(\frac{1}{4} - \frac{1}{n_i^2} \right)$$

$$0.1875 = 0.25 - \frac{1}{n_i^2}$$

$$\therefore \frac{1}{n_i^2} = 0.25 - 0.1875$$

$$\frac{1}{n_i^2} = 0.0625$$

$$n_i^2 = \frac{1}{0.0625}$$

$$n_i^2 = 16$$

$$n_i = 4 \quad \#$$