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ROLL No.: 16UEC111

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Physics-II Assignment-I

1. $m = 4 Kg$

$K = 196 Nm^{-1}$

$x = 1/4 m$

As, we know,

$$K = m\omega^2$$

$$\Rightarrow \omega = \sqrt{\frac{K}{m}} = \sqrt{\frac{196}{4}} = \sqrt{49} = 7$$

(a)

Also, $2\pi f = \omega$

$$\Rightarrow f = \frac{\omega}{2\pi}$$

$$f = \frac{7}{2\pi} = 1.114 Hz$$

Now, $T.E. = \frac{1}{2} m A^2 \omega^2$

$$= \frac{1}{2} \times 4 \times 0.25 \times 0.25 \times 49$$

$$= 6.125 J$$

(b)

Now, $E_2 - E_1 = nh\nu \quad [\because n = 1]$.

$$= h\nu$$

$$= 6.626 \times 10^{-34} \times 1.114$$

$$= 7.381 \times 10^{-34} J$$

Now, $n = \frac{E}{\Delta E} = \frac{6.125}{7.381 \times 10^{-34}} = 8.29 \times 10^{33}$

2. By Weins Law,

$$\lambda T = 2898\ K\mu m$$

$$\lambda = 446 nm = 446 \times 10^{3} \mu m$$

$$\therefore T = \frac{2898\ K\mu m}{446 \times 10^{3}\ \mu m} = \frac{2898 K}{446 \times 10^{3}} = 6.49 \times 10^{-3} K$$

Now, using Stefan's Law,

$$I = \sigma T^4$$

$$I = (5.67 \times 10^{-8}) \times (6.49 \times 10^{-3})^4$$

$$= 36.7983 \times 10^{-20}\ Wm^{-2}$$

$$\therefore I = 3.67 \times 10^{-19}\ Wm^{-2}$$

As we know,

$$\frac{dQ}{dt} = e \sigma T^4$$

Let the required tempr be t.

Now, $\frac{ms(20.5 - 20)}{60} = e \sigma T^4$ —— (i)

Also, $\frac{ms(t - 20.0)}{60} = e \sigma (2T)^4$ —— (ii)

Dividing (i) & (ii), we get:

$$\frac{0.5}{t - 20.0} = \frac{1}{16}$$

$$\Rightarrow t - 20.0 = 8$$

$$\Rightarrow t = 28.0$$

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$T = 98.6°F = 37°C$

$\therefore T = 310 K$.

Now, $\lambda T = 2898\ \mu m K$

$\lambda = \frac{2898}{310}\ \mu m = 9.34\ \mu m$

5. Given: $P = 0.5\ W$

$\lambda = 632 \times 10^{-9}\ m$.

$t = 20\ ms$

As we know, $E = nh\nu = \frac{nhc}{\lambda}$

Also, $P = \frac{E}{t}$

$\therefore \frac{nhc}{\lambda t} = 0.5$

$\Rightarrow \frac{n \times 6.62 \times 10^{-34} \times 3 \times 10^{8}}{632 \times 10^{-9} \times 20 \times 10^{-3}} = 0.5$

$\Rightarrow n = 3.1822 \times 10^{16}$

6. $K_{max} = h\nu - \phi$

Also, $K_{max} = \frac{hc}{\lambda} - \phi$

(a) Now, $11.390 \times 1.6 \times 10^{-19} = \frac{hc}{80 \times 10^{-9}} - \phi$ — (i).

$7.154 \times 1.6 \times 10^{-19} = \frac{hc}{110 \times 10^{-9}} - \phi$ — (ii)

Subtracting (ii) from (i), we get.

$4.236 \times 1.6 \times 10^{-19} = \frac{hc}{10^{-9}}\left(\frac{1}{80} - \frac{1}{110}\right)$

$\Rightarrow 6.786 \times 10^{-19} = \frac{h \times 3 \times 10^{8}}{10^{-9}} \times 3.40 \times 10^{-3}$

$\Rightarrow h = 6.635 \times 10^{-34}\ J\text{-}s$.

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(b) Using eqn (i), we get

$$\phi = \frac{6.635 \times 10^{-34} \times 3 \times 10^{8}}{80 \times 10^{-9}} - 1.822 \times 10^{-}$$

$$= 2.488 \times 10^{-18} - 1.822 \times 10^{-18}$$

$$= 0.666 \times 10^{-18}$$

$$\therefore \phi = 6.66 \times 10^{-19} J$$

Now, $\phi = h\nu_0$

$$\Rightarrow \nu_0 = \frac{\phi}{h} = \frac{6.66 \times 10^{-19}}{6.635 \times 10^{-34}}$$

$$\therefore \nu_0 = 1.0037 \times 10^{15} Hz$$

Also, $\nu_0 = \frac{c}{\lambda_0}$

$$\therefore \lambda_0 = \frac{c}{\nu_0} = 2.988 \times 10^{-7} m$$

$$\lambda = 298.8 nm$$

7. Given: $d = 1.5 \times 10^{-11} m$

$I = P/A = 1.4 \times 10^{3} Wm^{-2}$

$\nu = 5 \times 10^{14} Hz$

(a) $A = 1 m^2$; $t = 1s$

$\therefore P = I \times A = 1.4 \times 10^{3} W.$

$E = nh\nu = Pt.$

$$\Rightarrow n = \frac{Pt}{h\nu} = \frac{1.4 \times 10^{3} \times 1}{6.63 \times 10^{-34} \times 5 \times 10^{14}}$$

$$= 4.2 \times 10^{21} \text{ photons}/(s.m^2)$$

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Total Power(P) = $(P/A) \times 4\pi R^2_{E-S}$

$= (1.4 \times 10^3) \times 4\pi \times (1.5 \times 10^{11})$

$= 4.0 \times 10^{26}$ W

$\therefore n = \frac{P}{h\nu} = \frac{4.0 \times 10^{26}}{6.63 \times 10^{-34} \times 5 \times 10^{14}} = 1.2 \times 10^{45}$ photons/s

(c) The photons are all moving with same speed c, and in the same dir.n, (no. of photons per unit time per unit area is the product of the number per unit volume & the speed),

$n = \frac{4.2 \times 10^{21} \text{ photons}/(s.m^2)}{3 \times 10^8 \text{ m/s}}$

$= 1.4 \times 10^{13}$ photons/m^3.

8. By Compton Eqn,

$\lambda' - \lambda = \lambda_c (1 - \cos\phi)$

where, $\lambda_c = \frac{h}{mc} = 2.426 \times 10^{-12}$ m

$\lambda' = \lambda + \lambda_c (1 - \cos\phi)$

$\lambda' = 55.8 \times 10^{-12} + 2.426 \times 10^{-12} \times (1 - \cos 46°)$

$\lambda' = 55.8 \times 10^{-12} + 7.407 \times 10^{-13}$

$\lambda' = 56.540$ pm

9. $E = 3\times10^{3}\,eV = 3\times10^{3}\times1.6\times10^{-19}$

$= 4.8\times10^{-16}\,J$

$\phi = 60^\circ$

(a) By compton equ^{n},

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

$$= 2.426\times10^{-12}\times\frac{1}{2}$$

$$\lambda' - \lambda = 1.213\times10^{-12}\,m \quad \text{——— (i)}$$

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

$$\Rightarrow \overset{1.6}{\cancel{4.8}}\times10^{-13} = \frac{6.626\times10^{-34}\times\cancel{3}\times10^{8}}{\lambda}$$

$$\Rightarrow \lambda = \frac{6.626\times10^{-34}\times10^{8}}{1.6\times10^{-19}}$$

$$= 4.141\times10^{-10}\,m$$

$$\therefore \lambda = 414.1\,pm \quad \text{——— (ii)}$$

$$\therefore \lambda' = (414.1+1.213)\times10^{-12}\,m$$

$$\lambda' = 415.313\,pm.$$

$$\therefore E' = \frac{hc}{\lambda'} = 4.786\times10^{-16}\,J$$

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By Momentum conservation, in x-direction:

$$pC\cos\theta = h\nu - h\nu'\cos\phi \quad \text{— (iii)}$$

In y-direction,

$$pc\sin\theta = h\nu'\sin\phi \quad \text{— (iv)}.$$

Dividing (iii) & (iv), we get:

$$\cot\theta = \frac{\nu - \nu'\cos\phi}{\nu'\sin\phi}$$

$$= \frac{\frac{c}{\lambda} - \frac{c}{\lambda'}\cos\phi}{\frac{c}{\lambda'}\sin\phi}$$

$$= \frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\cos\phi\right)}{\frac{1}{\lambda'}\sin\phi}$$

$$= \frac{\lambda' - \lambda\cos\phi}{\lambda\sin\phi}$$

$$= \frac{(415.313 - 414.1\times\cos 60^\circ)\times 10^{-12}}{414.1\times 10^{-12}\times\sqrt{3}/2}$$

$$= \cancel{\frac{0.6067 \times 10^{-12}}{414.1\times 10^{-12}\times 0.866}}$$

$$= \frac{208.263\times 10^{-12}}{358.62\times 10^{-12}}$$

$$= 0.58$$

$$\cot\theta = \frac{\frac{c}{\lambda} - \frac{c}{\lambda'}\cos\phi}{\frac{c}{\lambda'}\sin\phi}$$

$$\cot\theta = \frac{\frac{1}{\lambda} - \frac{1}{\lambda'}\cos\phi}{\frac{1}{\lambda'}\sin\phi}$$

$$\cot\theta = \frac{\lambda' - \lambda\cos\phi}{\lambda\sin\phi}$$

$$\tan\theta = \frac{\lambda\sin\phi}{\lambda' - \lambda\cos\phi}$$

$$\theta = \tan^{-1}\left(\frac{1}{0.58}\right)$$

$$\therefore \theta = \tan^{-1}(1.724)$$

$$\therefore \theta = 59.886^\circ$$

10. Given: $\lambda = 10\,pm$

$\lambda' = 10.5\,pm$

By Compton eqⁿ, $\lambda' - \lambda = \lambda_c(1-\cos\phi)$

$(1-\cos\phi)$

$\therefore\ 0.5\times \cancel{10^{-12}} = 2.426\times\cancel{10^{-12}}$

$\Rightarrow\ 1-\cos\phi = 0.206$

$\Rightarrow\ \cos\phi = 0.794$

$\phi = 37.43^\circ$

As we know,

$$\cot\theta\ \cancel{\tan\theta} = \frac{\lambda' - \lambda\cos\phi}{\lambda\sin\phi}$$

$$= \frac{(10.5 - 10\times 0.794)\times 10^{-12}}{10\times 10^{-12}\times 0.608}$$

$\cancel{\cot\theta = \frac{2.56}{0.13}}$

$\cancel{\therefore\ \tan\theta = \frac{0.12}{2.58}}$

$\cancel{0.1184.08}$

$\cancel{\theta = \tan^{-1}\left(\frac{0.12}{2.56}\right)}$

$\cot\theta = \frac{2.56}{6}$

$\tan\theta = \frac{6}{2.56}$

$\theta = \tan^{-1}\left(\frac{6}{2.56}\right)$

$\boxed{\theta = 66.89^\circ}$

Now, Using Momentum conservation in y-dir.

$$p\cancel{c}\sin\theta = \frac{h\cancel{c}}{\lambda'}\sin\phi$$

$$p = \frac{h}{\lambda'}\frac{\sin\phi}{\sin\theta}$$

$$= 6.31\times 10^{-23}\times\left(\frac{0.013}{0.998}\right)$$

$$= 6.31\times 10^{-23}\times 0.013$$

$$\therefore\ p = 8.219\times 10^{-25}$$

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$E' = h\nu' = h\frac{\nu}{2}$ —— (i).

By Compton equ^n,

$\lambda' - \lambda = \frac{h}{mc}(1-\cos\phi)$ —— (ii)

$h\nu' = \frac{h\nu}{1+(h\nu/mc^2)(1-\cos\phi)}$

Equating (i) & (ii), we get :

$\frac{h\nu}{1+\frac{h\nu}{mc^2}(1-\cos\phi)} = \frac{h\nu}{2}$

$\therefore E = h\nu = (1-\cos\phi)mc^2$

Now, for E_{min} $\phi = 180°$

~~$\therefore E = mc^2 - h\nu$~~ [$m_e = 0.5$ MeV]

~~$= 0.5$ MeV $\times 931$ MeV~~

~~$E = 465.5$ MeV~~

Ans. 0.25 MeV

$E = \frac{mc^2}{2} = \frac{0.5\ \text{MeV}}{2} = 0.25$ MeV

12. Let the radius be x.

(a) $p = \frac{\hbar}{x}$

$K.E. = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{\hbar^2}{2mx^2}$

$P.E. = -\frac{Kq^2}{x} = \frac{-e^2}{4\pi\epsilon_0 x}$

$T.E. = K.E. + P.E.$

$= \frac{\hbar^2}{2mx^2} - \left(\frac{e^2}{4\pi\epsilon_0 x}\right)$

E should be min^m,

$\therefore \frac{dE}{dx} = 0$

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$$\frac{dE}{dx} = \frac{-h^2}{mx^3} + \frac{e^2}{4\pi\epsilon_0} \cdot \frac{1}{x^2} = 0$$

By solving the above equ^n, we get

$$x = 0.528 \text{ Å}$$

(b) $$E = \frac{h^2}{4\pi^2 \times 2 \times m \times x^2} - \frac{e^2}{4\pi\epsilon_0 \times x}$$

$$= 2.191 \times 10^{-18} - 4.357 \times 10^{-18}$$

$$\therefore \boxed{E = -2.166 \times 10^{-18} \text{ J}}$$

13. (a) $r = 0.01 \times 10^{-3}$ m $= 10^{-5}$ m

$Z = 1$

As we know, $r = 0.528 \times \frac{n^2}{Z}$ Å

$\Rightarrow n = 434.78 \approx 435$

(b) $E = -13.6 \times \frac{Z^2}{n^2}$ eV

$= 7.187 \times 10^{-5}$ eV

14. By compton equ^n,

$$\lambda' - \lambda = \frac{h}{m_p c^2}(1 - \cos\phi) \quad \text{— (i)}$$

$$\frac{1}{\nu'} - \frac{1}{\nu} = \frac{h}{m_p c^2}(1 - \cos\phi)$$

$$h\nu' = \frac{h\nu}{1 + (h\nu/m_p c^2)(1 - \cos\phi)}$$

Also, $KE_p = h\nu - h\nu'$

$$\therefore KE_p = h\nu - \frac{h\nu}{1 + (h\nu/m_p c^2)(1 - \cos\phi)}$$

for max^m K.E.p, $\theta = 180°$ (11)

$$\therefore \; K.E.p = \frac{h\nu}{1 + (m_p c^2 / 2h\nu)}$$

16. (a) By symmetry,
$P_2 = P$.

(b) Now, if the slit through which particle passes is observed, then the probability of the particle arriving at point Q is the sum of P_1 & P_2.
i.e., $P_1 + P_2 = P + P = 2P$.

17. $$\langle x|s\rangle = \sum_{\substack{i=1,2\\ \alpha=a,b,c}} \langle x|\alpha\rangle\langle\alpha|i\rangle\langle i|s\rangle$$

$$= \langle x|a\rangle\langle a|1\rangle\langle 1|s\rangle + \langle x|a\rangle\langle a|2\rangle\langle 2|s\rangle + \langle x|b\rangle\langle b|1\rangle\langle 1|s\rangle + \langle x|b\rangle\langle b|2\rangle\langle 2|s\rangle + \langle x|c\rangle\langle c|1\rangle\langle 1|s\rangle + \langle x|c\rangle\langle c|2\rangle\langle 2|s\rangle$$

15. (a) $\delta = \dfrac{2\pi a \sin\theta}{\lambda}$

$\sin\theta \approx \tan\theta \approx \dfrac{x}{D}$

$\delta = \dfrac{2\pi d x}{D\lambda}$

Maxima at $\delta = 2n\pi$

$2\pi \Delta n = \dfrac{2\pi d \Delta x}{D\lambda}$

Taking, $\Delta n = 1$

$$\Delta x = \frac{D\lambda}{d}$$

$m = 6.0 \times 12 \times 1.66 \times 10^{-27} = 1.1952 \times 10^{-23} \, kg$

(a) $\lambda = \frac{h}{p} = \frac{h}{mv} = 5.5458 \times 10^{-13} m$

$\Delta x = \frac{D\lambda}{d} = 4.6215 \times 10^{-5} m$

(b) velocity $= 117 ms^{-1}$