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PHYSICS TUTORIAL - 9

Q.1. No. of modes $N = \frac{8\pi \, d\lambda}{\lambda^4}$ $d\lambda = 20\times10^{-8}$ cm, $\lambda = 5\times10^{-5}$ cm

$$N = \frac{8\times3.14\times20\times10^{-8}}{(5\times10^{-5})^4}$$

$$= 8.038\times10^{11} \text{ Ans}$$

Q.2. (A) $\bar{E} = KT = 1.38\times10^{-23}\times1800 = 2.484\times10^{-20}$ J Ans

(B) $\bar{E} = \frac{h\nu/KT}{e^{h\nu/KT}-1} \times KT = \frac{2.12}{e^{2.12}-1} \times 2.484\times10^{-20} = 0.717\times10^{-20}$ J Ans

Q.3. $r_s = 7\times10^8$ m, $A_s = 4\pi r_s^2 = 4\times3.14\times(7\times10^8)^2$

$\sigma = 5.672\times10^{-8}$ W/m²K⁴

Total Energy radiated sun/sec $= U = A_s\sigma T^4 = 3.95\times10^{26}$ J

$R = 1.5\times10^{11}$ m

Energy reached per unit area per sec $= E_r = \frac{U}{4\pi r^2} = 1.4$ kW/m²

Q.4. $E = \sigma e A T^4 t$

$\frac{E}{t} = \sigma e A T^4 = 5$ J/sec

$e = 0.18$ Ans

Q.5. $\lambda_m T = \text{const} = 2.896\times10^{-3}$

$T = 6000$K Ans

Q.6. $E_A = \sigma e_A A_A T_A^4$

$E_B = \sigma e_B A_B T_B^4$

$\frac{E_A}{E_B} = \frac{e_A}{e_B}\frac{T_A^4}{T_B^4} \rightarrow T_B = 3T_A = 1934$K.

$$\lambda_m T = 2.9\times10^{-3}$$

$$\lambda_{m_A} = \frac{2.9\times10^{-3}}{5802} = 0.5\,\mu m$$

$$\lambda_{m_B} = 1.5\,\mu m$$

Physics Tutorial - 10

Q.1. $\lambda' = \lambda + \frac{h}{m_0 c}(1-\cos\theta)$. $\frac{h}{m_0 c} = 0.024\,\mathring{A}$

(i) $\lambda' = \lambda + \frac{h}{m_0 c}\times 2 = 1.45\,\mathring{A}$

(ii) $\lambda' = \lambda + \frac{h}{m_0 c} = 1.42\,\mathring{A}$

(iii) $\lambda' = \lambda + 0 = 1.4\,\mathring{A}$

Q.2. $\Delta x = 2\times10^{-10}$, $\Delta p.\Delta x = \frac{h}{4\pi}$

$$\Delta p = \frac{h}{4\pi\Delta x} = \frac{6.63\times10^{-34}}{4\times3.14\times2\times10^{-10}} = 2.635\times10^{-25}\ \text{kg m sec}^{-1}$$

$$p = \sqrt{2mK} = \sqrt{2\times9.1\times10^{-31}\times5000\times1.6\times10^{-19}}$$

$$= 3.818\times10^{-23}\ \text{kg m/s}.$$

$$\%\ \text{uncertainty} = \frac{\Delta p}{p}\times100 = 0.69$$

Q.3. $EGE = eV$

$$K.E = \frac{m_0c^2}{\sqrt{1-v^2/c^2}} - m_0c^2$$

$$eV = \frac{m_0c^2}{\sqrt{1-v^2/c^2}} - m_0c^2 \rightarrow \sqrt{1-\frac{v^2}{c^2}} = \frac{m_0c^2}{eV+m_0c^2}$$

$$1-\frac{v^2}{c^2} = \frac{m_0^2c^4}{(eV+m_0c^2)^2}$$

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$$v = \frac{c\sqrt{eV(eV+2m_0c^2)}}{eV + m_0c^2} \quad \text{—— (1)}$$

$$\lambda = \frac{h}{mv} = \frac{h\sqrt{1-v^2/c^2}}{m_0v} \quad \text{—— (2)}$$

putting (1) to (2) :

$$\lambda = \frac{hc}{\sqrt{eV(eV+2m_0c^2)}} \checkmark$$

Q.4. $\lambda = \dfrac{h}{mv}$, $v_g = v$

$$v = \frac{h}{m\lambda} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times1.2\times10^{-10}} = 6.06\times10^{6}\, m/s = v_g$$

$$v_p = \frac{\omega}{k} = \frac{E}{p} = \frac{p}{2m} = \frac{h}{2m\lambda}$$

$v_p = 3.03\times10^{6}\, m/s$ $\therefore$ $v_g = 2v_p$ ✓

Q.5 $\Delta p \Delta x \geq \dfrac{h}{4\pi}$ $\Delta v \Delta x \geq \dfrac{h}{4\pi m_0}$

$\Delta x = 10Å$, $m_0 = 9.11\times10^{-31}$, $h = 6.63\times10^{-34}$

$$\Delta v = \frac{h}{4\pi m_0 \Delta x} = 5.79\times10^{-5}\, m/s$$

Q.6. $v_g = v_p - \lambda \dfrac{dv_p}{d\lambda}$ $v_p = c\sqrt{\lambda}$

$$v_g = c\sqrt{\lambda} - \lambda \frac{c}{2\sqrt{\lambda}} = \frac{c\sqrt{\lambda}}{2} = \frac{v_p}{2} \checkmark$$

Q.7. m_p ; $m_d = 2m_p$, v_p , v_d

$K.E_p = \dfrac{m_p v_p^2}{2}$, $K.E_d = \dfrac{m_d v_d^2}{2} = m_d v_d^2$

$K.E_p = K.E_d \rightarrow$ $v_d = \dfrac{v_p}{\sqrt{2}}$ $\therefore$ $\dfrac{\lambda_d}{\lambda_p} = \dfrac{h/m_d v_d}{h/m_p v_p} = \dfrac{1}{2}\times\sqrt{2}$

$\lambda_d : \lambda_p = 1 : \sqrt{2}$ Ans

Physics Tutorial - 11

Q.1. Probability $= \int_0^{L/n} \frac{2}{L} \sin^2 \frac{n\pi x}{L} \, dx$

$$= \frac{2}{L}\int_0^{L/n} \frac{1}{2}\left(1 + \cos\frac{2n\pi x}{L}\right) dx = \frac{1}{L}\left[x + \frac{L}{2n\pi}\sin\frac{2n\pi x}{L}\right]_0^{L/n}$$

$$= \frac{1}{n}$$

Q.2. $E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$ for 1nm length of box

$E_n = 37.7 n^2 \, eV$

Ground State : $n=1$, $E_1 = 37.7 \, eV$

1st excited n : $n=2$, $E_2 = 150.8 \, eV$

$$\Delta E = E_2 - E_1 = 113.1 \, eV$$

Q.3. $E_n = \frac{n^2\hbar^2\pi^2}{2ml^2}$ for $m = 10g$, $L = 10cm$

$E_n = 3.4 \times 10^{-45} n^2 \, eV$

$E_1 = 3.4 \times 10^{-45} \, eV$

$E_2 = 13.6 \times 10^{-45} \, eV$

$E_3 = 30.6 \times 10^{-45} \, eV$

$E_1, E_2, E_3 \ldots$ are so close to each other they can't be observed seperately.

Q.4. $E_n = \frac{n^2\hbar^2\pi^2}{2mL^2} \Rightarrow E_2 - E_1 = \frac{3\hbar^2\pi^2}{2mL^2} = \frac{hc}{\lambda}$

$\lambda = 1103 \, nm \longrightarrow$ Infrared (no visible)

Q.5. $\int_{-\infty}^{\infty} \psi\psi^* \, dx = 1$

$\int_{-3a}^{a} c^2 \, dx = 1 \longrightarrow c^2 4a = 1 \longrightarrow c = \frac{1}{2\sqrt{a}}$ ✓

$\psi = \frac{1}{2\sqrt{a}}$

Probability in 0 to a $\int_0^a \frac{1}{2\sqrt{a}} \frac{1}{2\sqrt{a}} dx = \frac{1}{4}$ Ans

Q.6. $T = \frac{1}{100}$

$T = e^{-2\beta L} \rightarrow \ln\left(\frac{1}{T}\right) = 2\beta L$

$\beta = \frac{1}{2L} \times \ln\left(\frac{1}{T}\right) \approx 1.15 \times 10^{+10}$

$\beta = \frac{\sqrt{2m(V_0-E)}}{\hbar} = 1.15 \times 10^{10}$

$V_0 - E \approx 8.12 \times 10^{-19}$

$E \approx 0.925\, eV$ Ans

Q.7. $T = e^{-2\frac{\sqrt{2m(V_0-E)}}{\hbar}L}$

for $E_0 = 1eV$, $V = 10eV$, $L = 0.5nm$

$T_1 = 1.1 \times 10^{-7}$

(i) If Energy is doubled $T_2 \approx 2.4 \times 10^{-7}$ (slightly inc.)

(ii) " width of potential barrier is doubled $T_2 = 1.3 \times 10^{-14}$ (dec. T.P).