Tutorial Sheet- unit I (Quantum Mechanics) - (2023-24)

Sub. Name: Engineering Physics **Sub. Code: BAS - 201**

Date of Issue: **Date of Submission:**

1. Deduce the frequency corresponding to the maximum energy density in the radiation emitted from a black body at temperature 1000K? (**10^{14}sec^{-1}**).
2. A proton is moving with a speed of 2×10^{8} m/sec. Find the wavelength of wave associated with it. **(1.47×10^{-5} Å)**
3. A particle is moving in a one-dimensional box of width 25Å. Calculate the probability of finding the particle within an interval of 5Å at the centre of the box when it is in its state of least energy. (**0.40**) (***2010***)
4. Can a photon and electron of the same momentum have the same wavelength? Compare their wavelength if the two have the same energy. **($\lambda^{ph}/\lambda^{e} = \sqrt{(2mc^2/E)}$)** (***2005, 2012***)
5. Calculate the velocity and kinetic energy of a neutron having de-Broglie wavelength 1Å. (**0.082eV**)
6. Determine the probability of finding a particle trapped in a box of length L in the region from 0.45L to 0.55L for the ground state. **(19.8%)** (**2008, 2017)**
7. An x-ray of wavelength 1 Å are scattered at 90^0. Find the Compton shift and KE imparted to recoiling electron. **(.0243Å, 295eV**) **(2023 odd)**
8. In a Compton scattering experiment, x ray of wavelength 0.015Å is scattered at 60^o. Find the wavelength of the scattered X-ray**. (0.027**Å**)**
9. An X-ray photon is found to have its wavelength doubled on being scattered through 90^o. Find the wavelength and energy of incident photon. **(0.024**Å, **8.106×10^{-14} joules) (2022 odd)**
10. X-ray of wavelength 2Å are scattered from a black body and x-ray scattered at an angle 45^0. Calculate Compton shift $\Delta\lambda$, wavelength of scattered photon λ' (**Δλ= 0.007**Å**, λ'=2.007**Å**) (2018 even)**
11. An electron is bound in one dimensional box which has width 2.5Å. Assuming the height of the box to be infinite, calculate two lowest permitted energy values of the electron**. (6.04ev, 24.16ev)**
12. Calculate the energy difference between the ground sate and first excited state for an electron moving in one-dimension rigid box of length 25Å**. (0.175ev)** (**2022 even)**
13. Calculate the de-Broglie wavelength of an $\propto$ particle accelerated through a potential difference of 200 volts. **(0.00716 Å)**
14. An electron is trapped in one dimension region of length 1Å. Find the amount of energy that must be supplied to excite the electron from ground state to first excited state. **(113.07ev) (2022 even)**

Tutorial sheet (Unit 1) | 2023-24.

1) Weins displacement law

$\lambda_m T = \text{const}$

$\lambda_M (1000) = 0.3\times10^{-2}\ mK$

$\frac{c}{\nu_m} = 0.3\times10^{-2}$

$\nu_m \approx 10^{14}\ sec^{-1}$

2) $\lambda = h/p \quad P = m\upsilon = \frac{M_0 \upsilon}{\sqrt{1-\upsilon^2/c^2}}$

$M_0 = 1.67\times10^{-27}\ kg$

$\upsilon = 2\times10^{8}\ m/s$

$c = 3\times10^{8}\ m/s$

$\lambda = 1.47\times10^{-15}\ m$

3) $|\psi|^2 = \frac{2}{L}\sin^2\frac{\pi L/2}{L} \qquad x = L/2$

Prob for Δx

$P' = \frac{2}{L}\Delta x = \frac{2}{25}\times 5 = 0.4$

4) Acc. to De Broglie Concept

$P_e = \frac{h}{\lambda_e} \qquad P_{Ph} = \frac{h\nu}{c} = \frac{h}{\lambda_p}$

If $P_e = P_{Ph}$

$\Rightarrow \lambda_e = \lambda_p$ (Yes)

$\lambda_e = \frac{h}{m\upsilon} \qquad \lambda_e = \frac{h}{\sqrt{2mE}}$

$\lambda_{Ph} = \frac{h}{P}$ but $E = h\nu = \frac{hc}{\lambda} = Pc$

$\Rightarrow \lambda_{Ph} = \frac{hc}{E}$

To find λ_{Ph}/λ_e $\quad$ 1/2 $\quad \frac{\lambda_{Ph}}{\lambda_e} = \frac{hc}{E}\frac{\sqrt{2mE}}{h}$

$= c\sqrt{\frac{2m}{E}} = \sqrt{\frac{2mc^2}{E}}$

5) $\lambda = \frac{h}{m\upsilon} \Rightarrow \upsilon = \frac{h}{m\lambda}$

$\upsilon = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times10^{-10}} = 3.97\times10^{3}\ m/s$

$KE = \frac{1}{2}m\upsilon^2 = 1.316\times10^{-20}$ Joule $= .082$ eV

6) $\psi_n = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}$

$P = \int_{0.45L}^{0.55L} |\psi_n|^2 dx = \frac{2}{L}\int_{0.45L}^{0.55L}\frac{1}{2}\left(1-\cos\frac{2n\pi x}{L}\right)dx$

For least state put $n=1$

$P = \frac{1}{L}\left[x - \frac{\sin\frac{2\pi x}{L}}{2\pi/L}\right]_{0.45L}^{0.55L}$

$= \frac{1}{L}\left[(0.55L - 0.45L) - \left[\frac{L}{2\pi}(\sin 198 - \sin 162)\right]\right]$

$= 0.10 - \frac{\cos(180)\sin(18)}{\pi} = 0.198$

7) $\Delta\lambda = \frac{h}{m_0 c}(1-\cos\theta) = \frac{h}{m_0 c}(1-\cos 90)$

$= 0.0243\ \mathring{A}$

KE to the recoiled e^- $= h\nu - h\nu'$

$= \frac{hc}{\lambda} - \frac{hc}{\lambda'} = 4.72\times10^{-17}$ Joule

$= 295\ eV$

8) $\Delta\lambda = \frac{h}{m_0 c}(1-\cos\theta)$

$\lambda' - \lambda = \frac{h}{m_0 c}(1-\cos 60)$

$\lambda' = \lambda + \frac{h}{m_0 c}(1-\cos 60) = 0.027\ \mathring{A}$

9) $\Delta\lambda = \frac{h}{m_0 c}(1-\cos\theta)$

$2\lambda - \lambda = \lambda = \frac{h}{m_0 c}(1-\cos 90) = 0.0245\ \mathring{A}$

10) $\lambda = 2\mathring{A} \quad \theta = 45^\circ$.

$\Delta\lambda = \frac{h}{m_0 c}(1-\cos\theta) = \frac{h}{m_0 c}(1-\cos 45)$

$= 0.007\ \mathring{A}$

$\lambda' - \lambda = 0.007 \qquad \lambda' = 2 + 0.007 = 2.007\ \mathring{A}$

11) $E_n = \frac{n^2 h^2}{8mL^2} \qquad E_n = 9.66\times10^{-19} n^2$ Joule

$= 6.04\ n^2 eV$

$E_1 = 6.04\ eV \qquad E_2 = 24.16\ eV$

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12) $E_n = \frac{n^2 h^2}{8mL^2}$

$E_2 - E_1 = \frac{3h^2}{8mL^2}$

$= \frac{3 \times (6.62 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (25 \times 10^{-10})^2}$

$= 0.0028 \times 10^{-17}$ joules

$= 0.18$ eV.

13) $\lambda = \frac{h}{\sqrt{2mqV}}$

$m_\alpha = 4m_p \quad q_\alpha = 2e^-$

$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 4 \times 1.67 \times 10^{-27} \times 2 \times 1.6 \times 10^{-19} \times 200}}$

$= 7.16 \times 10^{-13}$ m

$= 0.00716$ Å

14) $E_n = \frac{n^2 h^2}{8mL^2} \Rightarrow E_{n=1} = \frac{h^2}{8mL^2}$

$E_{n=2} = \frac{4h^2}{8mL^2}$

$E_2 - E_1 = \frac{3h^2}{8mL^2} = 114$ eV.