
INDIAN INSTITUTE OF TECHNOLOGY DELHI

DEPARTMENT OF PHYSICS

MAJOR EXAM (PYL101)

Date: 9th June 2021, Time: 15:00 – 17:00 Hrs., Max. Marks: 50

- *There are total 9 questions in this question paper.*
- *All questions are compulsory. Use NEW PAGE for each question.*
- *In multiple-choice questions, marks will be given if ONLY the CORRECT Choice/Choices is/are marked.*
- *Marks for each question are indicated in brackets.*
- *All required constants & conversions are given at the end of the paper*

Question 1.

(i) In an experiment of photon interaction with a target material, 0.3 MeV photons are used. Assume the target to be a plain Cu sheet of unit atom thickness. The photons are expected to lose energy via: (1)

(a) Photoelectric effect
(b) Compton effect
(c) Both (a) & (b)

(ii) In the same experiment the student uses 3 eV photons instead; these photons are expected to lose energy via: (1)

(a) Photoelectric effect
(b) Compton effect
(c) Both (a) & (b)

(iii) Give analytical reasons for your choices in 1 & 2 above. (1)

(iv) If the wavelength of an incident radiation on a metal surface is increased from λ to $\lambda+d\lambda$, corresponding change in the stopping potential will be given by: (1)

(a) $\{h.c/(e\lambda^2)\}\ d\lambda$
(b) $-\{h.c/(e\lambda^2)\}\ d\lambda$
(c) $\{h.c/(e\lambda^2)\ d\lambda\}- d\varphi$
(d) $-\{h.c/(e\lambda^2)\ d\lambda\}- d\varphi$

Question 2.

Let $E(\lambda)d\lambda$ be the radiation emitted / second by a black body in the wavelength range between λ and $\lambda + d\lambda$. (3)

a. Make a qualitative plot for $E(\lambda)$ Vs. λ for T = 200K.
b. At T = 100K for the same body, with an estimate of the comparative area under the curves
c. At T = 200K for another black body with double the area of this black body.

[PLEASE NOTE: LABEL the axes before drawing the curves. Drawings alone are NOT SUFFICIENT to explain. So, to GET FULL MARKS YOU NEED TO EXPLAIN THE RELATIVE COMPARISONS WITH REASONS, in WORDS]

Question 3.

A typical electron travelling in a beam in a TV picture tube has an energy of ~ $2x10^{-15}$ J and a position uncertainty of 10^{-10} m. Calculate the uncertainty in its speed and the percentage (%) uncertainty of speed. (4)

Question 4.

Show that the ratio of Compton wavelength to de Broglie wavelength for a relativistic electron is given by – (3)

$\lambda_c / \lambda = [(E/mc)^2 - 1]^{1/2}$, where E is the total energy of electron and m is its mass

Question 5.

A He-Ne Laser beam with an intensity of $120 W/m^2$ is incident on Na surface (work-function =2.3 eV). Assuming electron to be confined to an area of Na atoms's radius (0.10nm), how long will it take for the surface to absorb enough energy to release an electron? What does the result tell you about the characteristic time for PE emission? (3)

Question 6.

Show that: $[\hat{P}_x{}^n, \hat{x}] = -ni\hbar \hat{P}_x{}^{n-1}$ (6)

Question 7.

The one-dimensional wavefunction of a particle is:

$$\psi(x) = \sqrt{2/a}\ sin\left(\frac{\pi x}{a}\right) \quad if\ 0 \le x \le a,$$
$$\psi(x) = 0 \quad \ldots elsewhere$$

Calculate:

(i) $\langle \hat{x}^2 \rangle$

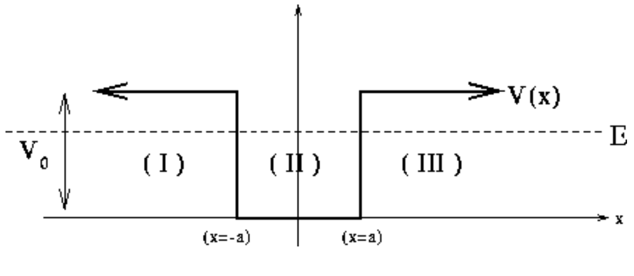
(ii) $\langle \hat{P}_x{}^2 \rangle$

(iii) $\sigma_x . \sigma_{P_x}$; *where* σ_x *and* σ_{P_x} *are uncertainties in position and momentum respectively.* [*Hint*: $\sigma_A = \sqrt{\langle (\Delta A)^2 \rangle}$, *where* $\Delta A = A - \langle A \rangle$]

(2+2+6)

Question 8.

Applying suitable boundary condition derive the wave functions of the ground state and first two excited states of one-dimensional infinite square well potential with origin at x=0 and width of 2a. Discuss what happens to it's solution if the potential is finite of depth V_0 as shown below:

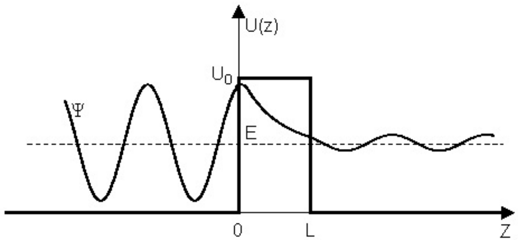


(4+6)

Question 9.

(a) Show that for a for a wide and high barrier (as shown below) that transmits poorly, the transmission coefficient for the barrier can be approximated as

$$T = \frac{16E}{U_0}\left(1 - \frac{E}{U_0}\right)e^{-2\beta L} \text{ ; where } \beta = \frac{2m}{\hbar^2}(U_0 - E)$$



(b) Two copper nanowires are insulated by a copper oxide nano-layer that provides a 10.0 eV potential barrier. Estimate the tunnelling probability between the nanowires by 7.00 eV electrons through a 5.00-nm thick oxide layer. (5+2)

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1 Å = 10^{-10} m, 1 eV = 1.6 x 10^{-19} J, 1 MeV =10^{6} eV, 1 W = 1 J/s

c = 3 x 10^{8} m/s, h = 6.6 x 10^{-34} J.s, Electron's mass = m_e = 9.1 x 10^{-31} kg

Electron's rest mass energy = m_ec^2 = 0.51 MeV,

Electron Compton wavelength = λ_C = 2.4 x 10^{-12} m

Bohr radius = a_0 = 5.3 x 10^{-11} m

Electron charge e = 1.6 x 10^{-19} C

Boltzmann Constant k = 1.38 x 10^{-23} J/K