I B.Tech. (2024-25) – I Semester - Engineering Physics (PHY 1071)

Mid Term Examination - Scheme of Evaluation

Type: MCQ

Q1. In a photoelectric effect experiment the stopping potential is (0.5)

1. ** the electric potential that causes the electron current to vanish
2. the energy required to remove an electron from the sample
3. the kinetic energy of the least energetic electron ejected
4. the potential energy of the most energetic electron ejected

Q2. What is the maximum kinetic energy (in eV) of a photoelectron when a surface, whose work function is 5.0 eV, is illuminated by photons whose wavelength is 400 nm? (0.5)

1. 3.1
2. –1.9
3. 1.9
4. ** 0

Q3. An optic glass fiber of refractive index 1.50 is to be clad with another glass to ensure total internal reflection that will contain light travelling within 5 degree of the fiber axis. The maximum index of refraction allowed for the cladding is, (0.5)

1. Equal to 1.60
2. ** Less than 1.49
3. Greater than 1.60
4. Greater than or equal to 1.60

Q4. Which of the following types of signal attenuation or distortion normally does not occur in single mode fibers? (0.5)

1. Scattering
2. Absorption
3. ** Intermodal dispersion
4. Material dispersion

Q5. The energy difference between the two laser levels is 0.117 eV. The frequency of emitted laser light from this laser would be (0.5)

1. ** 2.83 x 10^{13} Hz
2. 1.77 x 10^{14} Hz
3. 3.62 x 10^{14} Hz
4. 2.34 x 10^{15} Hz

Q6. For a particle in its ground state inside a box of length L, the probability density is maximum at (0.5)

1. ** x = L/2
2. x = 0
3. x = L
4. x = L/4

Q7. A free electron has a momentum of 5.0 × 10^{-24} kg m/s. The wavelength (in m) of its wave function is (0.5)

1. 1.3 × 10^{-8}
2. ** 1.3 × 10^{-10}
3. 1.3 × 10^{-12}
4. 1.3 × 10^{-6}

Q8. The ground state energy of an electron in a one-dimensional trap with zero potential energy in the interior and infinite potential energy at the walls is 2.0 eV. If the width of the well is doubled, the ground state energy will be (0.5)

1. ** 0.5 eV
2. 1 eV
3. 2 eV
4. 4 eV

Q9. Active region in a semiconductor laser is, (0.5)

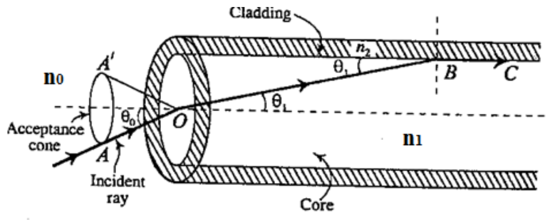
1. *n* region
2. ** intrinsic region
3. *p* region
4. conduction region

Q10. What is the quantum number, n of a particle of mass, m confined to a one-dimensional “box” of length, L when its energy is 2 h^2/mL^2? (0.5)

1. ** 4
2. 2
3. 8
4. 1

Type: DES

Q11. With necessary diagram, derive an expression for angle of acceptance and numerical aperture for an optical fibre. (4)



(1 Marks)

Applying Snell's law of refraction at *O*, we have,

$$\frac{\sin\theta_0}{\sin\theta_1} = \frac{n_1}{n_0}$$

$$\therefore\ \sin\theta_0 = \frac{n_1}{n_0}\sin\theta_1$$ (1 Marks)

Similarly, applying Snell's law at *B*,

$$\frac{\sin(90^\circ - \theta_1)}{\sin 90^\circ} = \frac{n_2}{n_1} \quad \textbf{or} \quad \cos\theta_1 = \frac{n_2}{n_1}$$

$$\sin\theta_1 = \sqrt{1 - \frac{n_2^2}{n_1^2}}$$ (1 Marks)

$$\sin\theta_0 = \frac{1}{n_0}\sqrt{n_1^2 - n_2^2}$$

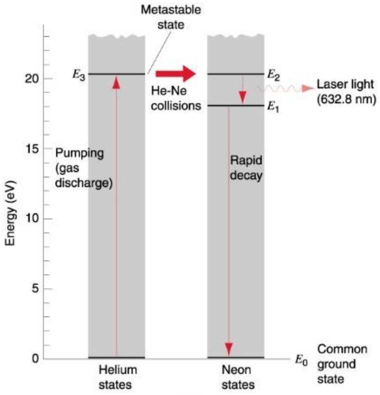
θ_0 is called the acceptance angle or half angle of the acceptance cone. The term $n_0 \sin\theta_0$ is called numerical aperture (*NA*). (1 Marks)

Q12. How does Einstein's photoelectric equation explain all the experimentally observed features of photoelectric effect. (3)

1. Equation shows that K_{max} depends only on frequency of the incident light. **(0.5 mark)**
2. Almost instantaneous emission of photoelectrons due to one -to –one interaction between photons and electrons. **(0.5 mark)**
3. Ejection of electrons depends on light frequency since photons should have energy greater than the work function ϕ in order to eject an electron. **(1 mark)**
4. The cutoff frequency f_c is related to ϕ by $f_c = \phi/h$. If the incident frequency f is less than f_c, there is no emission of photoelectrons. **(1 mark)**

Q13. Explain the operation of He-Ne laser with necessary energy level diagrams. (3)

He-Ne Laser has a glass discharge tube filled with He (80%) and Ne (20%) at low pressure. Helium gas is the "pumping" medium and Neon gas is the "lasing" medium (Figure 1). The simplified energy level diagram shows four levels: E_0, E_1, E_2 and E_3. Electrons and ions in the electrical gas discharge occasionally collide with He-atoms, raising them to level E_3 (a metastable state). During collisions between He- and Ne- atoms, the excitation energy of He-atom is transferred to Ne-atom (level *E_2*), selectively populating *E_2* due to resonant energy transfer. (1.5 Marks)



(Labelling-01 and showing transition-0.5= 1.5 Marks)

Q14. The nucleus of an atom is of the order of 2.0 x 10^{-14} m in diameter. For an electron to be confined to a nucleus its de Broglie wavelength would have to be on this order of magnitude or smaller. What would be the total relativistic energy of the electron? .(3)

Scheme:

The momentum of electron , $p_e = h / \lambda_e = 3.31 \times 10^{-20}$ kg.m/s

[1 mark]

Total energy, E, of the electron is given by $E^2 = p^2c^2 + m^2c^4 \Rightarrow E = 9.94 \times 10^{-12}$ J = **62.1 MeV**

[2 mark]

Q15. A step index optical fiber 60 μm in core-diameter has a core of refractive index 1.6 and a cladding of index 1.4. Determine (a) the critical angle for core-cladding interface, (b) the acceptance cone half-angle (the maximum entrance angle) .(3)

Scheme:

(a) $n_1 \sin i_c = n_2 \sin 90^0$.

$\sin i_c = \frac{n_2}{n_1}$,

$\sin i_c = \frac{1.4}{1.6}$

$\sin i_c = 0.875$, $i_c = 61^0$. **[1.5 mark]**

(b) $n_0 \sin\theta = n_1 \sin\theta_1$,

Here n_0 is the refractive index of air and is taken as 1, and θ_1 is the refraction angle. The refraction angle is given by

$\theta_1 = 90^0 - i_c$,

$\theta_1 = 90^0 - 61^0$,

$\theta_1 = 29^0$.

The acceptance angle, θ, is

$\sin\theta = 1.6 \times \sin 29^0$,

$\sin\theta = 0.77$,

$\theta = 50.4^0$ **[1.5 mark]**

Q16. An electron has a kinetic energy of 12.0 eV. The electron is incident upon a rectangular barrier of height 20.0 eV and thickness 1.0 nm. By what factor would the electron's probability of tunneling through the barrier increase assuming that the electron absorbs all the energy of a photon with wavelength 546 nm? .(3)

Scheme: $T \approx e^{-2CL}$

$$\text{where } C = \frac{\sqrt{2m(U - E)}}{\hbar}$$

$C = 1.4481 \times 10^{10}/m$

$T \approx e^{-2CL} = \mathbf{e^{-28.96}} = 2.642 \times 10^{-13}$ [1.5 mark]

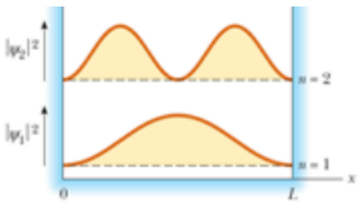
$$E' = E + \frac{hc}{\lambda} = 12 + 2.27 = 14.27 \text{ eV}$$

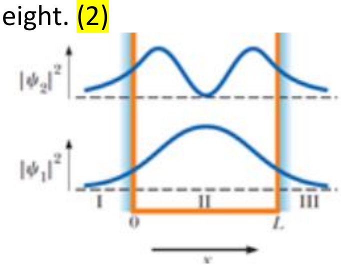
$C^1 = 1.2255 \times 10^{10}/m$

$T^1 = \mathbf{e^{-24.51}} = 2.267 \times 10^{-11}$

Hence, $\dfrac{T'}{T} = 86$ **[1.5 mark]**

Q17. Sketch the probability density for the first two energy states (n=1, n=2) for a particle in a potential well of infinite and finite height. (2)





[1+1 mark]

Q18. An electron has a kinetic energy of 3.0 eV. What is the corresponding wavelength of the electron. (2)

$K.E = 3.0 \text{ eV}$

$$\lambda = \frac{h}{\sqrt{2mK_e}} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.0 \times 1.6 \times 10^{-19}}}$$

$$= 7.09 \times 10^{-10} \text{ m}$$

[formula: 1 mark + answer: 1 mark]

Q19. In quantum model, the energy levels of a harmonic oscillator are quantized. Justify.

$$E_n = \left(n + \frac{1}{2}\right)\hbar\omega; \qquad n = 0, 1, 2 \ldots.$$

Use above equation and justify it for different value of n. **[equation: 1 mark + justification: 1 mark]**