Department of Physics

Manipal Institute of Technology

MAHE Manipal

APPLIED PHYSICS FOR ENGINEERS

PHY1072 (I Year Common Course for Computer Stream)

Mid Term Examination September 2024

Type: MCQ

Q1. What is the quantum number n of a particle of mass 'm' confined to one dimensional box of length "L" when its energy is $2h^2/mL^2$ (1)

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

Q2. What is the maximum change in the wavelength of Compton scattered radiation? (1)

1. ** 4.85 pm
2. 2.43 pm
3. 1.22 pm
4. 9.70 pm

Q3. What is the minimum uncertainty in velocity of an electron if uncertainty in its position is 50 pm? (1)

1. Zero
2. **1.16×10^{6} m/s
3. 1.05×10^{-24} m/s
4. 5.27×10^{-35} m/s

Q4. Choose the wrong statement from the following. (1)

1. A single mode step index optical fibre consists of a core having a uniform refractive index.
2. A multi mode step index optical fibre consists of a core having a uniform refractive index.
3. **Diameter of core is more for single mode step index optical fibre as compared to that of multi mode step index optical fibre.
4. Material dispersion in optical fiber is due to wavelength dependence of refractive index of the core.

Q5. Which part of laser system is responsible for directionality of laser? (1)

1. Lasing medium

2. Pumping system

3. **Cavity resonator

4. Electrical power supply

Type: DES

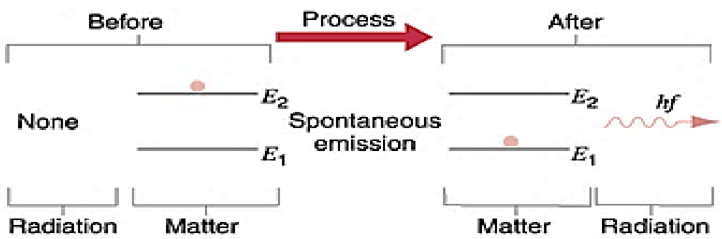
Q6. Explain the following terms with reference to lasers: (a) spontaneous emission (b) stimulated emission. Give an example each. (3)

Spontaneous emission is the emission of a photon when a system transits from a higher energy state to a lower energy state **without the aid of any external agency.**

The **average life time** of the atomic system in the excited state is of the order of **10^{-8} s.** After the life time of the atomic system in the excited state, it comes back to the state of lower energy on its own accord by emitting a photon of energy $hf = E_2 - E_1$

Example: LED, All emissions from normal excited states.

1M



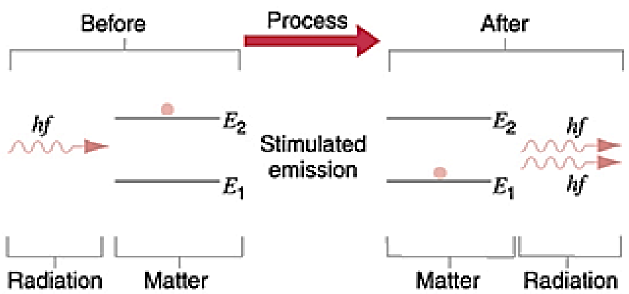
½ M

When a photon (called ***stimulating photon***) of suitable frequency interacts with an excited atomic system, the latter comes down to ground state before its life time. Such an emission of radiation is called stimulated emission.

In stimulated emission, ***both the stimulating photon and the stimulated photon are of same frequency***, ***same phase and are in same state of polarization***. These photons are emitted in the same direction. In other words, these two photons are coherent.

Example : LASER

1M



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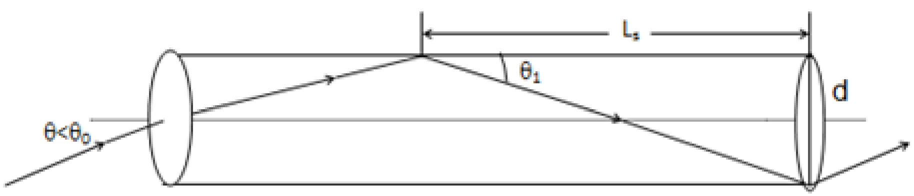
Q7. Define skip distance and derive an expression for it. (2)

Skip distance is the distance between two successive reflections of the ray of light which propagates through the optical fibre.

½ M



½ M

From the Figure,

$L_s = d\,\cot\theta_1 \; = \; d\,\sqrt{cosec^2\theta_1 - 1}$ **½ M**

$L_s = \; d\,\sqrt{\dfrac{n_1^2}{n_0^2\,\sin^2\theta} - 1} \quad (\because \sin\theta_1 = \dfrac{n_0}{n_1}\,\sin\theta\,)$ **½ M**

Q8. A step-index optical fiber has a core refractive index =1.48 and a cladding refractive index =1.46. The core radius of the fiber is 4 μm and the operating wavelength is 1550 nm. Calculate the following: a) The critical angle for total internal reflection at the core-cladding interface. b) The numerical aperture (NA) of the fiber. c) The maximum acceptance angle in air. (3)

a) $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = 80.6^0$ **1M**

b) $NA = \sqrt{n_1^2 - n_2^2} = 0.24$ **1M**

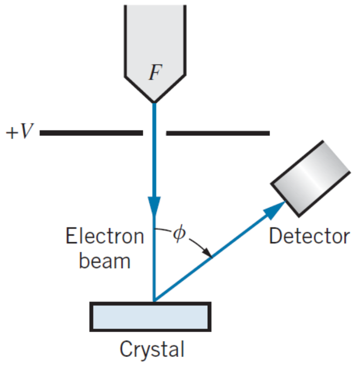
c) $\boldsymbol{\theta_0 = \sin^{-1}(NA) = \; 13.9^0}$ **1M**

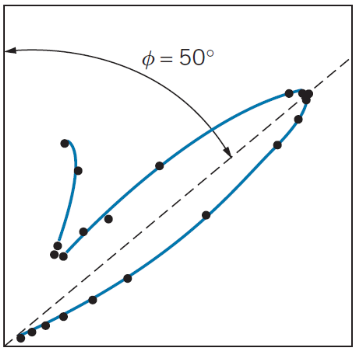
Q9. Calculate the ratio of Einstein's coefficients for a system at 300 K in which radiations of wavelength 1.39 μm are emitted. (2)

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h f^3}{c^3} = \frac{8\pi h}{\lambda^3}$$ **1M**

$=6.2 \times 10^{-15}$ **1M**

Q10. How Davison and Germer experiment validated the de Broglie hypothesis? Explain. (3)





1M

The result of this experiment resembles the result of the x ray diffraction giving experimental evidence for de Broglie hypothesis. A beam of electrons from a heated filament accelerated to a potential *V* is collimated and allowed to strike a single crystal of nickel. Electrons are scattered in all directions by the atoms in the crystal. The intensity of the scattered electron beam is measured by a detector which can be moved to any angle ϕ relative to the incident beam and is shown in the polar plot of ϕ verses the intensity ($\propto$ r, the radius vector). **1M**

$\therefore$ de Broglie wavelength, $\quad \lambda = \dfrac{h}{p} = \dfrac{h}{mv} = \dfrac{h}{\sqrt{2\,m\,e\,V}}$

Wavelength can also be obtained, in this experiment, using Bragg's law of diffraction. According to which the wavelength is given by the following relationship:

$d\,\sin\phi = n\lambda$ **1M**

The values of the wavelength from both the approaches agree very well. This verifies de Broglie's hypothesis and establishes the wave nature of electrons.

Q11. When a photosensitive metal is illuminated by light of certain wavelength, the stopping potential required to stop the ejected photoelectrons was found to be 1.1 V. If the incident wavelength is half the threshold wavelength of the metal, find (a) threshold frequency, (b) work function of the metal and also (c) the maximum velocity of the ejected electrons. (3)

Using the give data we can write : $K=eV=h(2f_c)-h(f_c)$

which gives us : $eV=hf_c$	½ M
$f_c=eV/h=$ **2.66×10^{14} Hz**	1M
Work function = hf_c = **1.76×10^{-19} J = 1.1 eV**	½ M
$v=(2 \times eV/m)^{1/2}$ = **6.22×10^5 m/s**	1M

Q12. The radius of our Sun is 6.96×10^8 m, and its total power output is 3.85×10^{26} W. Assuming that the Sun's surface emits as a black body, calculate its surface temperature. (2)

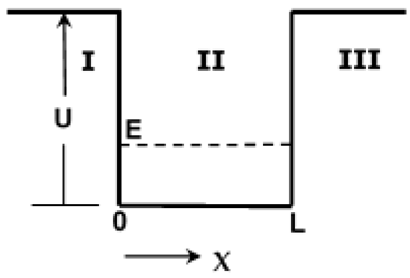
From Stefan's law, $P = eA\sigma T^4$. If the sun emits as a black body, $e = 1$.

$$T = \left(\frac{P}{eA\sigma}\right)^{1/4}$$ **1M**

$$= \left[\frac{3.85\times10^{26}\ \mathrm{W}}{1\left[4\pi\left(6.96\times10^{8}\ \mathrm{m}\right)^2\right]\left(5.67\times10^{-8}\ \mathrm{W/m^2\cdot K^4}\right)}\right]^{1/4}$$

$$= \boxed{5.78\times10^{3}\ \mathrm{K}}$$ **1M**

Q13. Show that the wave function of a particle trapped in a finite potential well decays exponentially with distance outside the well. (3)



Consider a particle with the total energy *E*, trapped in a finite potential well of height *U* such that

$$U(x) = 0 \quad \text{for} \quad 0 < x < L$$

$$U(x) = U \quad \text{for} \quad x \le 0,\ x \ge L$$

Classically, for energy *E* < *U*, the particle is permanently bound in the potential well. However, according to quantum mechanics, a finite probability exists that the particle can be found outside the well even if *E* < *U*. That is, the wave function is generally nonzero in the regions I and III. In region II, where *U* = 0, the allowed wave functions are again sinusoidal. But the boundary conditions no longer require that the wave function must be zero at the ends of the well. **1M**

Schrödinger equation outside the finite well in regions I & III

$$\frac{d^2\psi}{dx^2} = \frac{2m}{\hbar^2}(U-E)\,\psi \quad \text{or} \quad \frac{d^2\psi}{dx^2} = C^2\,\psi$$

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

General solution of the above equation is

$$\psi(x) = Ae^{Cx} + B\,e^{-Cx}$$

where *A* and *B* are constants. **1M**

A must be zero in Region III and *B* must be zero in Region I, otherwise, the probabilities would be infinite in those regions. For solution to be finite, $\psi_I = Ae^{Cx}$ for $x \leq 0$ $\psi_{III} = Be^{-Cx}$ for $x \geq L$ This shows that the wave function outside the potential well decay exponentially with distance.	**1M**
Q14. (a) An electron is confined in an infinite potential well of width 0.2 nm. Find the speed of the electron in the n =1 state. (b) A quantum simple harmonic oscillator consists of an electron bound by a restoring force proportional to its position relative to a certain equilibrium point. The proportionality constant is 8.99 N/m. What is the longest wavelength of light that can excite the oscillator? (4) (a) Given: L = 0.2nm, n = 1, E_1 = ?, v = ? We have, $E_n = \left(\frac{h^2}{8\ m\ L^2}\right) n^2$ $E_1 = \left[\frac{(6.626\times10^{-34})^2}{8\times9.1\times10^{-31}\times(0.2\times10^{-9})^2}\right](1)^2$ = **1.507×10^{-18} J** = 9.42 eV	**1M**
Since, $E = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2E}{m}}$ $= \sqrt{\frac{2\times1.507\times10^{-18}}{9.1\times10^{-31}}}$ = **1.819×10^6 m/s**	**1M**
Given : k = 8.99 N/m, λ = ? The longest wavelength corresponds to minimum photon energy, which must be equal to the spacing between energy levels of the oscillator. From ΔE = ℏω , we have $\frac{hc}{\lambda} = \frac{h}{2\pi}\sqrt{\frac{k}{m}}$ $\lambda = 2\pi c\sqrt{\frac{m}{k}}$	**1M**
$= 2\pi\left(3.00\times10^8\ \text{m/s}\right)\left(\frac{9.11\times10^{-31}\ \text{kg}}{8.99\ \text{N/m}}\right)^{1/2}$ i.e., **λ = 600 nm**	**1M**

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