R. Nikam

PILLAI COLLEGE OF ENGINEERING, NEW PANVEL
(Autonomous) (Accredited 'A+' by NAAC)
END SEMESTER EXAMINATION
SECOND HALF 2021

BRANCH: FE (MECH/AUTO)

Subject: Engineering Physics – I | **Time: 02.00 Hours**
Max. Marks: 45 | **Date: 06-04-2022**

N.B 1. Q.1 is compulsory
2. Attempt any two from the remaining three questions

Q.1.	Attempt all	M	BT	CO
a)	What are LASERS? Give the distinguishing characteristics of LASER light.	3	1	1
b)	Explain Numerical Aperture (NA) in Optical Fibers. How does the value of NA change with the refractive index of the surrounding medium?	3	2	2
c)	Apply Heisenberg's Uncertainty Principle to prove the non-existence of electrons in the nucleus.	3	3	3
d)	Distinguish between Type I and Type II superconductors with a relevant diagram. Why TYPE II superconductors find more applications in comparison to TYPE I?	3	2	4
e)	Prove that Divergence of Curl of a vector field is zero.	3	3	6
Q.2.	Attempt all			
a)	Explain the construction and working of He-Ne laser.	4	2	1
b)	Derive Maxwell's 3rd and 4th equations in integral and differential form and give their significance.	5	3	6
c)	Determine the transition temperature and the critical field at 4.2 K for a given specimen of a superconductor if the critical fields are 1.41×10^5 A/m and 4.205×10^5 A/m at 1.41 K and 12.9 K respectively.	6	4	4
Q.3.	Attempt all			
a)	What is a hologram? Describe the process of recording and reconstruction of hologram.	4	2	1
b)	Assuming Schrodinger's Time dependent equation, derive one dimensional Schrodinger's Time Independent equation.	5	2	3
c)	A step index fibre has a core diameter of 29 μm. The refractive indices of core and cladding are 1.52 and 1.5189 respectively. If the light of wavelength 1.3 μm is transmitted through the fibre, determine: (i) Numerical Aperture of the fibre(surrounding medium is air) (ii) Normalized frequency of the fibre (iii) The number of modes the fibre can support	6	3	2

Q.4.	Attempt all		
a)	Give the important assumptions of the BCS theory and hence explain formation of Cooper pairs in a superconductor.	4	
b)	Explain with relevant diagrams, the following terms related to LASERS: i)Spontaneous emission ii)Stimulated emission iii)Metastable state iv)Population inversion v)Pumping	5	1
c)	An electron is bound in a one dimensional infinite potential well of width 2 Å. Find its energy in the ground state and in first two excited states. What happens to the gap between consecutive energy levels(states) of the potential well, with increasing value of 'n'?.	6	

CO1- Explain the functioning of lasers and their various applications.

CO2-. Able to explain the working principle of optical fibres and their applications especially in the field of communication

CO3-.Explain the limits of Classical Physics and apply the fundamentals of quantum mechanics to study the one dimensional motion of microscopic particles.

CO4- Apply the knowledge of superconductivity to SQUID and Magnetic levitation.

CO5- Apply the reasons for Acoustic defects and use this in the proper design of a Hall/Auditorium and use the knowledge of Piezoelectric and Magnetostriction effect for production of ultrasonic waves and its application in various fields

CO6-Apply the knowledge of coordinate systems and vector calculus to various situations. Also the learner will be able to study further as the base is set in this topic.

BT Levels: - 1 Remembering ,2 Understanding, 3 Applying,4 Analyzing, 5 Evaluating, 6 Creating.

M-Marks, BT- Bloom's Taxonomy, CO-Course Outcomes.

Mech / Auto.

1 a) Light Amplification by Stimulated Emission of radiation (LASERS) (1+2M)

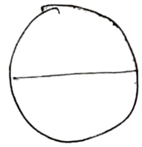
(i) Highly monochromatic (ii) highly intense

(iii) Low angular divergence (iv) very high power concentrated in very small area.

b) N.A. of an optical fiber is light accepting capacity of the fiber. $N.A = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$ (2M+1M)

As the R.I. of surrounding medium increases N.A. decreases.

Q.1 c) Non existance of electron in the nucleus. (3M)



maximum uncertainty in the measuring position of electron is Δx = Diameter of the nucleus.

$\Delta x \Delta p_x = \hbar$ $\Delta x = 10^{-15}$ m

$\Delta p_x = \frac{\hbar}{\Delta x} = \frac{h}{2\pi \Delta x} = \frac{6.63 \times 10^{-34}}{2\pi \times 10^{-15}}$

$\Delta p_x \simeq P$

$\Delta p_x = 1.05 \times 10^{-19}$ kg m/s.

Energy of the electron

$E = PC = 1.05 \times 10^{-19} \times 3 \times 10^8$

$= 3.16 \times 10^{-11}$ J

$1 eV = 1.6 \times 10^{-19}$ J

$1 MeV = 1.6 \times 10^{-13}$ J

$E = \frac{3.16 \times 10^{-11}}{1.6 \times 10^{-13}}$ MeV

$= 197.8$ MeV

$E \simeq 200$ MeV

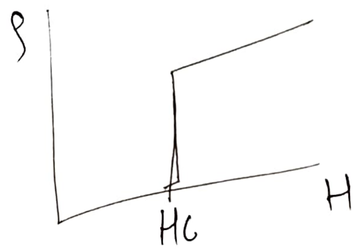
During nuclear transformation when neutron is converted into proton β particles are emitted which has energy equal to 3 to 4 M eV which proves that electron dose not exist in the nucleus.

Q.1 d) Type I & Type II superconductors (3M)

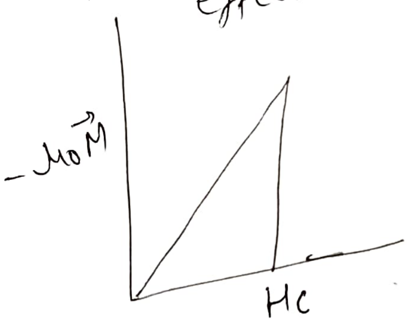
Type I

① Transition from superconducting state to normal state or normal state to superconducting state is sharp & at Hc

② It has only one value of critical magnetic field (CHc)



③ obey complete Meissner effect.



④ Very low value of Hc = 0.1 to 0.2 T

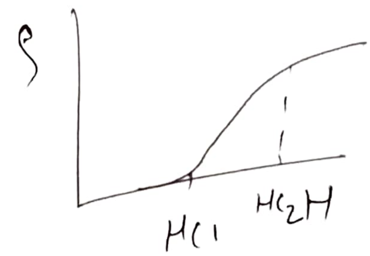
⑤ Limited applications in industry

⑥. e.g. Pb, Hg, Al etc.

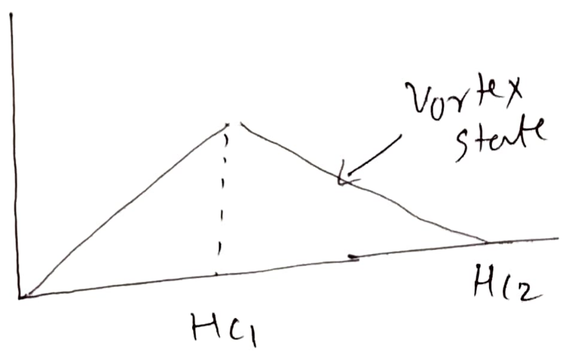
Type II

Transition from Normal state superconducting state is gradu when applied field changes from HC1 to HC2

Two Critical magnetic fields (CHC1 & HC2)



obey Meissner effect only upto HC1



④ very High value of HC2 around 30 to 50 T

⑤ Very high applications of Type-II superconductors in industry.

⑥ Alloys of transition metals Ceramic materials.

$\nabla \cdot \text{Curl } F = \left(\vec{i}\frac{\partial}{\partial x} + \vec{j}\frac{\partial}{\partial y} + \vec{k}\frac{\partial}{\partial z} \right) \cdot$ (3M)

$$\left[\vec{i}\left(\frac{\partial F_3}{\partial y} - \frac{\partial}{\partial z}F_2\right) - \vec{j}\left(\frac{\partial F_3}{\partial x} - \frac{\partial F_1}{\partial z}\right) + \vec{k}\left(\frac{\partial F_2}{\partial x} - \frac{\partial F_1}{\partial y}\right) \right]$$

$$\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_1 & F_2 & F_3 \end{vmatrix}$$

$$= \frac{\partial^2 F_3}{\partial x \partial y} - \frac{\partial^2 F_2}{\partial x \partial z} - \frac{\partial^2 F_3}{\partial y \partial x} + \frac{\partial^2 F_1}{\partial y \partial z} + \frac{\partial^2 F_2}{\partial z \partial x} - \frac{\partial^2 F_1}{\partial z \partial y}$$

$$= 0$$

Q. 2 a) Construction & working of He-Ne laser (2M+2M) (4 Marks)

b) Maxwell's 3^{rd} & 4^{th} equation in integral & differential form & their significance (2M+3M) (5 Marks)

$$\oint_C \vec{E} \cdot d\vec{l} = EMF_{total} = -\frac{\partial \phi}{\partial t}$$

By stokes theorem

$$\oint_C \vec{E} \cdot d\vec{l} = \int_S (\nabla \times \vec{E}) \cdot d\vec{s}$$

$$\int_S \nabla \times E \cdot d\vec{s} = -\frac{\partial \phi}{\partial t}$$

$$\int_S \vec{B} \cdot ds = \phi = \int d\phi$$

$$\int_S \nabla \times \vec{E} \cdot ds = -\frac{\partial}{\partial t} \int_S \vec{B} \cdot d\vec{s}$$

$$\boxed{\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}}$$ $\Rightarrow$ Diff form of

3^{rd} Maxwell's eqn

$$\oint_C \vec{E}\cdot d\vec{l} = -\int_S \frac{\partial \vec{B}}{\partial t}\cdot ds$$ Integral form of 3rd Maxwell's eqn

4th Maxwell's eqn. Circulation of $\vec{H}$ round the closed loop is equal to current enclosed by that loop.

$$\oint_C \vec{H}\cdot d\vec{l} = I_{enclosed}$$ → Ampere's circuital law.

By stokes thm line integral is converted into ~~curl of~~ surface integral of curl of vector field.

$$\oint \vec{H}\cdot dl = \int_S (\nabla\times\vec{H})\cdot ds \qquad \int_S \vec{J}\cdot d\vec{s} = I_{enclosed}$$

$$\boxed{\nabla\times\vec{H} = J}$$ — (1) point form of Ampere's law.

$$Div(curl\ \vec{H}) = 0 \qquad \nabla\cdot(\nabla\times\vec{H}) = Div\vec{J} = 0$$

Comparing this eqn with equation of continuity

$$Div\vec{J} + \frac{\partial \rho}{\partial t} = 0$$

eqn (1) is valid only when $\frac{\partial \rho}{\partial t} = 0$

Thus Amper's law is inconcistant with eqn of continuity. Maxwell argued that there should be one more term in the R.H.S. of the eqn.

$$\boxed{\nabla\times\vec{H} = \vec{J} + \frac{\partial D}{\partial t}}$$ where $\frac{\partial D}{\partial t}$ = displacement curr

→ Differential form of 4th Maxwell's eqn.

$$\oint \vec{H}\cdot d\vec{l} = \mu_0\epsilon_0 I + \mu_0\epsilon_0\frac{\partial \phi_E}{\partial t}$$
$$= \mu_0\epsilon_0(I + I_d)$$

↳ Integral form of 4th Maxwell's eqn.

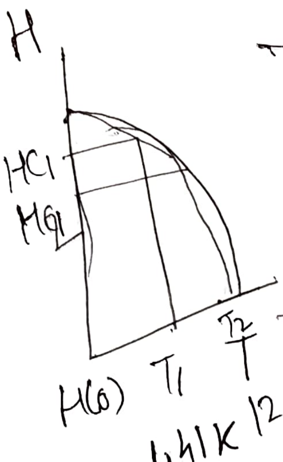
$$H_c(T) = H_c(0)\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

$H_c(4.2K) = ?$ (6M)

$H_c(1.41K) = 1.41\times10^5\ A/m$

$H_c(12.9K) = 4.205\times10^5\ A/m$

$$\frac{H_c(1.41K) = H_c(0)\cdot\left[1-\left(\frac{1.41}{T_c}\right)^2\right]}{H_c(12.9K) = H_c(0)\cdot\left[1-\left(\frac{12.9}{T_c}\right)^2\right]} \quad \text{—(1), —(2)}$$



$$\frac{1.41\times10^5}{4.205\times10^5} = \frac{\left[1-\frac{(1.41)^2}{T_c^2}\right]}{\left[1-\frac{(12.9)^2}{T_c^2}\right]}$$

$$1.41\times10^5\left[1-\frac{(12.9)^2}{T_c^2}\right] = 4.205\times10^5\left[1-\frac{(1.41)^2}{T_c^2}\right]$$

$$1.41\times10^5\left[\frac{T_c^2-(12.9)^2}{T_c^2}\right] = 4.205\times10^5\left[\frac{T_c^2-(1.41)^2}{T_c^2}\right]$$

$$\frac{1.41\times10^5\,T_c^2}{T_c^2} - \frac{1.41\times10^5(12.9)^2}{T_c^2} = \frac{4.205\times10^5\,T_c^2}{T_c^2} - \frac{4.205\times10^5(}{T_c^2}$$

$$\frac{1.41\times10^5}{4.205\times10^5} = \frac{T_c^2-(1.41)^2}{\cancel{T_c^2}} \times \frac{\cancel{T_c^2}}{T_c^2-(12.9)^2}$$

$$1.41\times10^5(T_c^2-166.41) = 4.205\times10^5(T_c^2-1.9881)$$

$4.205\times10^5 T_c^2$ ~~$- 1.41\times10^5 T_c^2 = 1.41\times10^5$~~

$\times 10^{5}\, T_c - 2.3\times 10^{7} = 4.205\times 10^{5}\, T_c^2 - 8.35\times 10^{5}$

$4.205\times 10^{5}\, T_c^2 - 1.41\times 10^{5}\, T_c^2 = 8.35\times 10^{5} - 2.3\times 10^{7}$

$$\frac{0.3353}{1} = \frac{T_c^2 - 1.9881}{T_c^2 - 166.41}$$

$0.3353\, T_c^2 - 0.3353\times 166.41 = T_c^2 - 1.9881$

$T_c^2 - 0.3353\, T_c^2 = -0.3353\times 166.41 + 1.9881$

$(1 - 0.3353)\, T_c^2 = -55.79 +$

$= -53.81$

$0.6647\, T_c^2 = -53.81$

$$-\frac{\hbar^2}{2m}\frac{\partial^2 \psi(x,t)}{\partial x^2} + V\,\psi(x,t) = -i\hbar \frac{\partial \psi(x,t)}{\partial t} \quad (5M)$$

1-D Time dependent schrodinger's wave eqn.

$\psi(x,t) = A e^{i(kx - \omega t)}$ $\quad \omega = \frac{E}{\hbar}$

$= A e^{ikx} \cdot e^{-\omega t}$

$= A e^{i/\hbar (px - Et)}$

$= A e^{i/\hbar\, px} \cdot e^{-\frac{iEt}{\hbar}}$

$= \psi(x) \cdot e^{-iEt/\hbar}$

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2}\cdot e^{-iEt/\hbar} + V\psi(x)\cdot e^{-\frac{iEt}{\hbar}} = \psi(x)\, e^{-iEt/\hbar}$$

$$\frac{\partial \psi}{\partial t} = \psi(x)\, e^{-\frac{iEt}{\hbar}}\left(\frac{-iE}{\hbar}\right)$$

$i\hbar \frac{\partial \psi(x,t)}{\partial t} = \psi(x) e^{-\frac{iEt}{\hbar}}$

$$\frac{\partial \psi(x,t)}{\partial x} = \frac{d\psi(x)}{dx}\cdot e^{-iEt/\hbar}$$

$$\frac{\partial^2 \psi(x,t)}{\partial x^2} = \frac{d^2\psi(x)}{dx^2}\cdot e^{-iEt/\hbar}$$

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi(x) = E\psi(x)$$

1-D TISWE

Q.3 c)

$$V = \frac{\pi d}{\lambda} \cdot N.A. \qquad NA = \sqrt{n_1^2 - n_2^2}$$

$d = 29\ \mu m$

$n_1 = 1.52$, $n_2 = 1.5189$

$\lambda = 1.3\ \mu m$

$$N.A = \sqrt{(1.52)^2 - (1.5189)^2}$$

$$= \sqrt{3.34279 \times 10^{-3}}$$

$$\boxed{N.A = 0.0578}$$ — Ans. (2M)

Normalized freq / V-number $= \frac{\pi d}{\lambda} \cdot NA$

$$= \frac{\pi \times 29\ \mu m}{1.3\ \mu m} \cdot 0.0578$$

$$\boxed{V = 4.05}$$ (2M) — Ans.

$$N_M = \frac{V^2}{2} = 8.20$$

(2M)

Number of modes supported = 8 — Ans.

Q.4 c)

$$E_n = \frac{n^2 h^2}{8 m L^2}$$

for $n=1$, E_1 = ground state.

$n=2$, E_2 = first excited state

$n=3$, E_3 = second excited state

(2M)

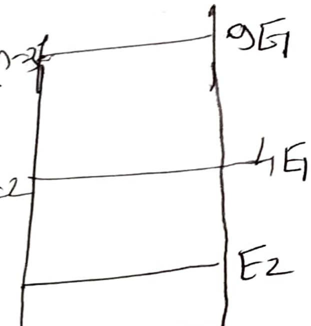
$$E_1 = \frac{(6.63 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (2 \times 10^{-10})^2}$$

$$\boxed{E_1 = 1.509 \times 10^{-18}\ J}$$

$E_2 = 4E_1 = 6.038 \times 10^{-18}\ J$

$E_3 = 9E_1 = 1.358 \times 10^{-17}\ J$

(4M)



Gap between consecutive energy levels will increase with increasing value of 'n'.