Module – 4 : Introduction to Electromagnetic Theory:

General form of Maxwell's equations:

$$\vec{\nabla}.\vec{E} = \frac{\rho}{\epsilon}$$

$$\vec{\nabla}.\vec{B} = 0$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \times \vec{B} = \mu \vec{J} + \mu\epsilon \frac{\partial \vec{E}}{\partial t}$$

Conduction current density: $\vec{J} = \sigma\vec{E} \equiv \vec{J_c}$

Displacement current density: $\vec{J_d} = \epsilon\frac{\partial \vec{E}}{\partial t} = K\epsilon_0\frac{\partial \vec{E}}{\partial t}$

Questions:

1. Investigate the formation of electromagnetic wave within a capacitor and inductor in an electrical circuit having AC voltage source. **(5) [BL4]**

[**Hints:** Draw the circuit with the capacitor and inductor. Using the concept of Maxwell's equations, indicate the formation of electric field and magnetic field within the capacitor and inductor.]

2. A parallel plate capacitor with circular plates of radius 2.5 cm and the plates are 5 mm apart. The plates are connected to a AC voltage source 180 sin 30 πt . Find the maximum displacement current. **(5) [BL4]**

[**Hint:** Use formula of displacement current density**.**]

3. Consider a parallel plate capacitor immersed in sea water. The charge on the capacitor is varied according to $q = q_0 sin 2\pi\nu t$, where ν = 4 $\times$ 10^8 Hz. At this frequency sea water has permittivity ϵ = 81 ϵ_0 , permeability $\mu = \mu_0$ and resistivity ρ = 0.23 Ω-m. Find out the ratio of the amplitudes of the conduction and the displacement current densities between the plates. **(5) [BL5]**

[**Hints:** Using the form of the variation of charge on the capacitor plate, calculate the electric field as a function of time. Using the form of the electric field obtained calculate the conduction current density and displacement current density.]

4. A parallel plates capacitor with circular plates of radii *R* is being charged. Derive an expression

for the induced magnetic field around a circular path of radius $r<R$.Assume the electric field within the plates to be uniform without any edge effect. Evaluate $\vec{B}$ for $r = R = 55\ mm$ and $\frac{dE}{dt} = 1.5 \times 10^{12}$V/ms**. (5) [BL5]**

[**Hints:** Use Maxwell's equations.]

5. TEM wave of frequency 300 GHz propagates in vacuum along the +*ve*X-direction. It has an electric field of amplitude 28.28 *m*. The wave is linearly polarized with the plane of vibration of the electric field at an angle 45^0 to the X-Z plane. Evaluate the expression of $\vec{E}$ and $\vec{B}$. **(10) [BL5]**

[**Hint:**TEM wave propagates along X-direction. So $E_x = 0$, $B_x = 0$]

Module – 5 : Quantum Mechanics

Quantum Mechanical Wave Functions and Operators.

In Quantum Mechanics we can associate a wavefunction ψ with every particle. All observables in Quantum Mechanics (for example Energy, Momentum and Position) can be represented as operators. An operator has to be Hermitian in order to qualify to be a Quantum Mechanical Operator.

Following table shows different operators corresponding to different observables,

Observable Name	Observable Symbol	Operator Symbol	Operator Operation
Position	$\underline{\mathbf{r}}$	$\hat{\mathbf{r}}$	Multiply by $\underline{\mathbf{r}}$
Momentum	$\mathbf{p}$	$\hat{\mathbf{p}}$	$-i\hbar\left(\hat{i}\frac{\partial}{\partial x}+\hat{j}\frac{\partial}{\partial y}+\hat{k}\frac{\partial}{\partial z}\right)$
Kinetic energy	T	$\hat{T}$	$-\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)$
Potential energy	$V(\mathbf{r})$	$\hat{V}(\mathbf{r})$	Multiply by $V(\mathbf{r})$
Total energy	E	$\hat{H}$	$-\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)+V(\mathbf{r})$
Angular momentum	l_x	$\hat{l}_x$	$-i\hbar\left(y\frac{\partial}{\partial z}-z\frac{\partial}{\partial y}\right)$
	l_y	$\hat{l}_y$	$-i\hbar\left(z\frac{\partial}{\partial x}-x\frac{\partial}{\partial z}\right)$
	l_z	$\hat{l}_z$	$-i\hbar\left(x\frac{\partial}{\partial y}-y\frac{\partial}{\partial x}\right)$