2015

(6th Semester)

PHYSICS

ELEVENTH PAPER

(Electromagnetic Theory)

Full Marks : 55

Time : 2½ hours

(PART : B—DESCRIPTIVE)

(*Marks* : 35)

The figures in the margin indicate full marks for the questions

1. *(a)* Give the statement of Faraday's law of electromagnet. 2

(b) Starting from Maxwell's equations, show that the electric field satisfies the following differential equation in a homogeneous medium containing charges and currents :

$$\nabla^2\vec{B} - \mu\varepsilon\frac{\partial^2\vec{B}}{\partial t^2} = \mu\sigma\frac{\partial\vec{B}}{\partial t}$$

Where the notations in the equation have their usual meanings. 3

(c) What is displacement current? Calculate the displacement current through a parallel-plate air-filled capacitor of area 10 cm^2 separated by a distance 2 mm and connected to 360 volts and frequency of 1 MHz source. 2

Or

(a) Derive the Maxwell's equation

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

where $\vec{D}$ is electric displacement and $\vec{J}$ is the current density. 3

(b) Using Maxwell's equations, discuss the boundary conditions satisfied by the magnetic field vector at the interface between two different media. 4

2. (a) Derive the general equation for electromagnetic wave equation in free space and hence show that the propagations of electric and magnetic fields are in phase. 3+1=4

(b) An electromagnetic wave travelling with a 10 GHz frequency in free space has an amplitude of 10 V/m in positive x-direction. Calculate the values of the wave velocity, the wavelength and the impedance of the wave. 3

(Continued)

Or

(a) Define the Poynting vector and hence explain the radiation pressure of an electromagnetic wave. 2+2=4

(b) Define the electromagnetic momentum and express it in its vector form. 2+1=3

3. *(a)* Discuss the propagation of electromagnetic wave in perfectly dielectric medium. 4

(b) Explain in brief the polarization of electromagnetic wave. 3

Or

(a) What is the total internal reflection of an electromagnetic wave? Show that the wave is totally reflected back at total internal reflection. 4

(b) Explain in brief the skin depth and the skin effect in an electromagnetic wave. 3

4. What are the scalar and vector potentials in electromagnetic waves? Derive the Poisson's equation using vector potential with the current density. 2+5=7

Or

Discuss the transformation of electro-magnetic wave by using Lorentz gauge transformation and explain how the Lorentz gauge is used to explain the wave theory.

3+4=7

5. Derive the Cauchy's dispersion formula applicable to the electromagnetic theory

$$\mu = A + \frac{B}{\lambda^2}$$

where A and B are Cauchy's constants and λ is the wavelength of the wave. 7

Or

Explain Rayleigh scattering of electro-magnetic radiation and thus derive the expression for the scattering cross- section $\sigma = \left(\frac{\omega}{\omega_0}\right)^2 \sigma_T$, where the symbols used have their usual meanings.

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(PART : A—OBJECTIVE)

(*Marks* : 20)

The figures in the margin indicate full marks for the questions

SECTION—I

(*Marks* : 5)

Put a Tick ☑ mark against the correct answer in the box provided : 1×5=5

1. The integral form of Maxwell's equation originated from Faraday's law of electromagnetic induction is

(a) $\int \vec{D} \cdot \vec{ds} = \int \rho_v dV$ ☐

(b) $\int \vec{B} \cdot \vec{ds} = 0$ ☐

(c) $\oint_C \vec{H} \cdot \vec{dl} = \int \vec{I}_C \cdot \vec{ds} + \int \frac{\partial \vec{D}}{\partial t} \cdot \vec{ds}$ ☐

(d) $\oint_C \vec{E} \cdot \vec{dl} = -\int \frac{\partial \vec{B}}{\partial t} \cdot \vec{ds}$ ☐

2. The intrinsic impedance of electromagnetic wave is

(a) $\frac{\mu_0 \omega}{k}$ ☐

(b) $\frac{\mu_0 k}{\omega}$ ☐

(c) $\frac{\varepsilon_0 \omega}{k}$ ☐

(d) $\frac{\varepsilon_0 k}{\omega}$ ☐

where the symbols used have their usual meanings.

3. For normal incidence of an electromagnetic wave from media 1 to 2, the ratio of transmitted intensity to the incident intensity is

(a) $R_n = \left(\frac{n_2 + n_1}{n_2 - n_1}\right)^2$ ☐

(b) $R_n = \left(\frac{n_1}{n_2 + n_1}\right)^2$ ☐

(c) $R_n = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2$ ☐

(d) $R_n = \left(\frac{n_2}{n_2 + n_1}\right)^2$ ☐

where n_1 and n_2 are the refractive indices of the dielectric media 1 and 2 respectively.

4. For any electromagnetic wave, the dispersion relation gives the relation between the

(a) wave number k and velocity of the wave v ☐

(b) wave number k and frequency ω ☐

(c) velocity of the wave v and intensity i ☐

(d) wave number k and intensity i ☐

5. The energy radiated by an oscillating electric dipole is represented by

(a) $\vec{S} = \frac{1}{\varepsilon_0 \mu_0} (\vec{E} \times \vec{B})$ ☐

(b) $\vec{S} = \frac{1}{\mu_0} (\vec{E} \times \vec{B})$ ☐

(c) $\vec{S} = \frac{1}{\varepsilon \mu} (\vec{E} \times \vec{B})$ ☐

(d) $\vec{S} = \frac{1}{\varepsilon_0} (\vec{E} \times \vec{B})$ ☐

SECTION—II

(*Marks* : 15)

Give very short answers to the following questions : $3\times5=15$

1. Electromagnetic wave is propagated in a material medium. Show that the Maxwell's equations for curl $\vec{B}$ becomes

$$\vec{\nabla}\times\vec{B}=\mu_0\left[\vec{J}_f+\vec{\nabla}\times\vec{M}+\frac{\partial\vec{P}}{\partial t}\right]+\frac{1}{c^2}\frac{\partial\vec{E}}{\partial t}$$

where the notations in the equation have their usual meanings.

2. Define the energy density of electromagnetic wave.

3. State and explain Brewster's law in electromagnetic waves.

4. Explain the non-uniqueness of the magnetic and scalar potential

8. What is the meaning of TE mode in the propagation of the electromagnetic wave?

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