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(CBCS)

(6th Semester)

PHYSICS

TENTH PAPER

(Electromagnetic Theory)

Full Marks : 75

Time : 3 hours

(PART : A—OBJECTIVE)

(*Marks* : 25)

The figures in the margin indicate full marks for the questions

SECTION—A

(*Marks* : 10)

Put a Tick (✓) mark against the correct answer in the brackets provided : 1×10=10

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

(a) $\vec{D}\ \overline{ds}$ dV ( )

(b) $\vec{B}\ \overline{ds}$ 0 ( )

(c) $\circ_C \vec{H}\ \overline{dl}$ $\overline{I_C}\ \overline{ds}$ $\frac{\vec{D}}{t}\ \overline{ds}$ ( )

(d) $\circ_C \vec{E}\ \overline{dl}$ $\frac{\vec{B}}{t}\ \overline{ds}$ ( )

2. Energy density in a magnetic field $\vec{B}$ is given by

(a) $\frac{B^2}{2\ _0}$ ( ) *(b)* $\frac{B^2}{2\ _0}$ ( )

(c) $2\ _0 B$ ( ) *(d)* $\frac{2\ _0}{B}$ ( )

3. When a plane electromagnetic wave enters from one medium into another, which of the following quantities remains unchanged?

(a) Frequency ( )

(b) Electric field amplitude ( )

(c) Wavelength ( )

(d) Velocity ( )

4. The speed of light in free space is

(a) $\frac{1}{\sqrt{2\ _0\ _0}}$ ( ) *(b)* $\sqrt{\ _0\ _0}$ ( )

(c) $\sqrt{\frac{_0}{_0}}$ ( ) *(d)* $\frac{1}{\sqrt{\ _0\ _0}}$ ( )

5. For normal incidence of an e.m. wave from media 1 to 2, the ratio of reflected intensity to the incidence intensity is (n_1 and n_2 are refractive indices at the two media)

(a) $\left(\frac{2n_1}{n_1\ \ n_2}\right)^2$ ( ) *(b)* $\left(\frac{n_1\ \ n_2}{n_1\ \ n_2}\right)^2$ ( )

(c) $\left(\frac{n_1\ \ n_2}{n_1\ \ n_2}\right)^2$ ( ) *(d)* $\left(\frac{2n_2}{n_1\ \ n_2}\right)^2$ ( )

6. The boundary conditions for perpendicular component of electric field at a conducting surface is

(a) $E_1\ \ E_2$ ( ) *(b)* $_2E_1\ \ _1E_2$ ( )

(c) $_1E_1\ \ _2E_2\ \ _f$ ( ) *(d)* $_1E_1\ \ _2E_2\ \ _f$ ( )

7. If the vector and scalar potentials in a region of space are respectively $\vec{A}$ and V, then the magnetic field there exists is

(a) $\vec{\nabla} \times \vec{A}$ ( ) *(b)* $\vec{\nabla} V$ ( )

(c) $\vec{\nabla} \times \vec{A} - \vec{\nabla} V$ ( ) *(d)* $\vec{\nabla} \times \vec{A} + \vec{\nabla} V$ ( )

8. An electric field $\vec{E}$ in terms of scalar V and vector potential $\vec{A}$ is

(a) $\vec{\nabla} V - \dfrac{\vec{\partial A}}{t}$ ( )

(b) $\vec{\nabla} V + \dfrac{\vec{\partial A}}{t}$ ( )

(c) $\vec{\nabla} \times \vec{A} - \dfrac{V}{t}$ ( )

(d) $\vec{\nabla} \times \vec{A} + \dfrac{V}{t}$ ( )

9. According to Wien's displacement law of blackbody radiation, ($_{max}$ peak wavelength, T absolute temperature, a proportionality constant)

(a) $_{max} = \dfrac{a}{T}$ ( )

(b) $_{max} = \dfrac{a}{T^2}$ ( )

(c) $_{max} = aT$ ( )

(d) $_{max} = aT^2$ ( )

10. Identify the correct statement.

(a) Rayleigh-Jeans law agrees with experimental results at short wavelength. ( )

(b) Inconsistency in Rayleigh-Jeans law occur at large wavelength. ( )

(c) Rayleigh-Jeans law agrees experimental results at large wavelength but strongly disagrees at short wavelength. ( )

(d) Planck's law is an approximation of Rayleigh-Jeans law. ( )

SECTION—B

(*Marks* : 15)

Answer the following questions : 3×5=15

1. What is displacement current? Explain its significance. How does it relate with electric polarization?

OR

2. Using Maxwell's equation, show that $E_1^{\parallel}$ $E_2^{\parallel}$ at the boundary between two different media.

3. Consider an electromagnetic wave in empty space whose electric field is given by

$$\vec{E} \quad 60\hat{x} \exp[\ i(10^8 t \quad 4z)]$$

Determine the magnetic field of the wave.

OR

4. Write down the four Maxwell's equations in both vacuum and material media. Define all the terms used in the expression.

5. The constitutive parameters of aluminium are given by $_r$ 1, $_r$ 1, $_0$ 4 $10^{\ 7}$ H/m and 3 54 10^7 mho/m. Find the frequency for which the skin depth of aluminium is 0·01 mm.

OR

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

7. Express Lorentz force equation in terms of the scalar and vector potentials of electromagnetic field.

OR

8. Obtain the expression for scalar potential of magnetic dipole.

9. Write a brief note on Planck's law of blackbody radiation.

OR

10. Explain the term 'population inversion' in laser system. How can it be achieved?

(PART : B—DESCRIPTIVE)

(*Marks* : 50)

The figures in the margin indicate full marks for the questions

1. *(a)* Explain Faraday's law of electromagnetic induction. From Faraday's law, establish the relation $\vec{E} \rightarrow \frac{\vec{B}}{t}$, where the symbols have their usual meanings. 2+5=7

(b) Obtain the expression for energy stored in an inductor. 3

OR

2. *(a)* Discuss the inconsistency of Ampere's law. Explain how Maxwell fixed Ampere's law and obtain the expression for modified Ampere's law. 2+4=6

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

3. Using Maxwell's equations in free space, deduce the wave equations satisfied by the electric field vector and the magnetic field vector. Obtain their plane wave solution and hence show that electromagnetic waves are transverse in nature. Also show that $\frac{|\vec{E}|}{|\vec{B}|}$ c, speed of light in free space. 4+4+2=10

OR

4. Define Poynting vector. State and prove Poynting theorem. 2+1+7=10

5. Derive Fresnel equations for reflection and refraction of electromagnetic waves at a plane boundary separating two media when the incident wave is polarized with E vector parallel to the plane of incidence. Find the angle of incidence for which there is no reflected wave. 8+2=10

OR

6. *(a)* Starting from Maxwell's electromagnetic equations, show that an electromagnetic wave is damped inside a conducting medium. 6

(b) Explain the phenomenon of total internal reflection in electromagnetic waves from electromagnetic theory. 4

7. Explain Coulomb gauge and Lorentz gauge conditions. Use Lorentz gauge to deduce the Poisson's equations satisfied by the electromagnetic potentials in non-static conditions. Comment on these equations for static conditions. 3+5+2=10

OR

8. What are the scalar and vector potentials in e.m. waves? Discuss their non-uniqueness. Show that the electromagnetic potentials satisfy the wave equation. 3+4+3=10

9. Establish the Stefan-Boltzmann law of blackbody radiation and hence establish an expression for radiation pressure. 7+3=10

OR

10. *(a)* Derive the necessary equations to express the Einstein's A and B coefficients in laser system. 6

(b) Explain how laser action can be achieved by considering a three-level laser system. 4

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