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(CBCS)

(6th Semester)

PHYSICS

TENTH PAPER

(Electromagnetic Theory)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. In a region of space where there exists static charge distribution, the electric field will be defined by the relation (symbols have their usual meanings)

(a) $\vec{\nabla} \cdot \vec{E} = \frac{\vec{B}}{t}$, $\vec{\nabla} \times \vec{E} = 0$ ( )

(b) $\vec{\nabla} \cdot \vec{E} = 0$, $\vec{\nabla} \times \vec{E} = 0$ ( )

(c) $\vec{\nabla} \cdot \vec{E} = \frac{\vec{B}}{t}$, $\vec{\nabla} \times \vec{E} = -$ ( )

(d) $\vec{\nabla} \cdot \vec{E} = 0$, $\vec{\nabla} \times \vec{E} = -$ ( )

2. If $\hat{n}$ is unit normal vector at the interface between two dielectric media, then the relation that holds for parallel and perpendicular component of electric displacement vector is

(a) $\vec{D}_1^{||} \quad \hat{n} \quad D_1^{||}$ ( )

(b) $\vec{D}_1 \quad \hat{n} \quad D_1$ ( )

(c) $\vec{D}_1 \quad \hat{n} \quad 0$ ( )

(d) $D_1 \quad 2D_2$ ( )

3. SI unit of Poynting vector is

(a) watt m^2 ( )

(b) joule $s^{1} m^2$ ( )

(c) joule m^2 ( )

(d) watt $s^{1} m^2$ ( )

4. Intensity of an electromagnetic wave in terms of an electric field is

(a) $\frac{E_0^2}{2c_{0}}$ ( )

(b) $\frac{cE_0^2}{2_{0}}$ ( )

(c) $\frac{cE_0^2}{2_{0}}$ ( )

(d) $\frac{c_{0}E_0^2}{2}$ ( )

5. For an e.m. wave propagation from one dielectric medium to another dielectric medium, the relation between incident, reflected and transmitted wave vectors is (where n_1 and n_2 are refractive indices of the first and second media)

(a) $k_I \quad k_R \quad \frac{n_1}{n_2} k_T$ ( )

(b) $k_I \quad k_R \quad \frac{2n_1}{n_2} k_T$ ( )

(c) $k_I \quad k_R \quad \frac{n_1}{2n_2} k_T$ ( )

(d) $k_I \quad k_R \quad \frac{n_1}{n_2} k_T$ ( )

6. For an electromagnetic wave travelling from free space to a good conductor, the reflection R and transmission T coefficients are

(a) R T ( )

(b) R T ( )

(c) R 0, T 1 ( )

(d) R 1, T 0 ( )

7. The magnetic flux density $\vec{B}$ for a given magnetic vector potential $\vec{A}$ $x\hat{i}$ $2x\hat{j}$ $z\hat{k}$ is

(a) $4\hat{i}$ ( ) *(b)* $\hat{j}$ ( )

(c) $\hat{k}$ ( ) *(d)* $2\hat{k}$ ( )

8. The expression for d'Alembertian operator is

(a) ^{2} $\frac{^2}{t^2}$ ( )

(b) ^{2} $\frac{^2}{t^2}$ ( )

(c) ^{2} $\frac{^2}{t^2}$ ( )

(d) ^{2} $\frac{^2}{t^2}$ ( )

9. The laser action is primarily associated with

(a) stimulated emission ( )

(b) spontaneous emission ( )

(c) blackbody radiation ( )

(d) spontaneous radiation ( )

10. The wavelength corresponding to the maximum energy of solar emission is 4700 Å. The temperature of the Sun is (constant in Wien's displacement law is 0·2989)

(a) 8000 K ( ) *(b)* 7223 K ( )

(c) 6166 K ( ) *(d)* 5060 K ( )

(SECTION : B—SHORT ANSWER)

(*Marks* : 15)

Answer the following questions : 3×5=15

UNIT—I

1. What is sheet current? What will be the value of sheet current at the interface between two dielectric media? Write the relation between parallel component of magnetic field at such interface.

OR

2. Show that $\vec{} \quad \vec{E} \quad \frac{\vec{B}}{t}$.

UNIT—II

3. Show that in an electromagnetic wave propagation $|\vec{B}_0| \quad \frac{1}{c}|\vec{E}_0|$, where c is the speed of light.

OR

4. Show that magnitude of Poynting vector $S \quad \frac{E^2}{c_{\ 0}}$.

UNIT—III

5. Consider light travelling from air ($n_1 \quad 1$) into glass ($n_2 \quad 1\ 5$) at normal incidence. Calculate reflection and transmission coefficients.

OR

6. Calculate skin depth of an electromagnetic wave (with angular frequency 10^{15} Hz) in a good conductor having conductivity 10^{7} S/m. Given permeability $4 \quad 10^{7}$ N/A^{2}.

UNIT—IV

7. Show that Lorentz condition is invariant under gauge transformations for which the gauge function is a solution to the homogeneous wave equations.

OR

8. Obtain an expression for momentum of a charge particle in an electromagnetic field.

UNIT—V

9. What do you mean by population inversion in laser system? Briefly explain how population inversion can be achieved in a two-level laser system.

OR

10. Write down the statement of Stefan-Boltzmann law. Express its mathematical relation and define all the symbols.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer the following questions : 10×5=50

UNIT—I

1. *(a)* What do you mean by steady and non-steady current? Explain this concept from continuity equation. Also discuss the inconsistency of Ampere's law for non-steady current. 1+2+2=5

(b) Obtain the expression of modified Ampere's law. Explain in brief the concept of displacement current. 3+2=5

OR

2. *(a)* For an inductor with self-inductance L, show that the work done by an external source to raise the current from 0 A to I ampere is

$$W \quad \frac{LI^2}{2}$$

From this expression further deduce that in an inductor, energy is stored in the form of magnetic field around the conducting coil. 3+3=6

(b) Show that if $B_0 \quad \frac{E_0}{v}$, the following time varying electric and magnetic fields satisfy Maxwell's equations in vacuum

$$\vec{E} \quad E_0 \sin(y \quad vt)\hat{k}$$
$$\vec{B} \quad B_0 \sin(y \quad vt)\hat{i}$$

where E_0 and B_0 are constants. $v \quad \frac{1}{\sqrt{\quad_0 \quad_0}}$ 4

UNIT—II

3. *(a)* Starting from Maxwell's equation in free space, show that light is an electromagnetic wave. 4

(b) Prove that an electromagnetic wave is transverse in nature. 6

OR

4. *(a)* Obtain average energy density $\langle U_{em} \rangle$ of an e.m. wave. 4

(b) Obtain the expression for momentum carried by an e.m. wave and pressure exerted by an e.m. wave on a surface. 3+3=6

UNIT—III

5. Obtain expressions for reflection and transmission coefficients for an electromagnetic wave travelling from one dielectric medium to another dielectric medium and falling at 90° at the interface. 10

OR

6. Obtain Fresnel equations for reflection and refraction of electromagnetic waves at a plane boundary separating two media (either parallel or perpendicular polarization). What is Brewster's angle? 8+2=10

UNIT—IV

7. Starting with Maxwell's equations, obtain an expression for electric and magnetic fields in terms of electromagnetic potentials. Also obtain Maxwell's equations in terms of electromagnetic potentials. 4+6=10

OR

8. *(a)* What is Coulomb gauge? Show that under Coulomb gauge, Maxwell's equation reduces to Poisson's equation. 1+3=4

(b) What are gauge transformation relations? Show that electromagnetic potentials are not unique. 6

UNIT—V

9. Deduce Planck's law of blackbody radiation. Also obtain Wien's displacement law. 10

OR

10. *(a)* What are emissive power and absorptive power? State and prove Kirchhoff's law. 2+4=6

(b) What do you mean by population inversion in laser system? Briefly explain how population inversion can be achieved in a two-level laser system. 4

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