2024

(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. The direction of the induced e.m.f. in a circuit is given by

   (a) Faraday's law ( )

   (b) Fleming's left-hand rule ( )

   (c) Lenz's law ( )

   (d) Ampere's law ( )

2. The differential form of Ampere's law in magnetostatics is

(a) $\vec{\nabla} \times \vec{B} = -\mu_0 \vec{J}$ ( )

(b) $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}$ ( )

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

(d) $\vec{\nabla} \times \vec{B} = \frac{\partial \vec{B}}{\partial t}$ ( )

3. Which of the following has coulomb as the unit?

(a) $\oint \vec{H} \cdot \overrightarrow{dl}$ ( )

(b) $\oint \vec{E} \cdot \overrightarrow{dl}$ ( )

(c) $\oint \vec{D} \cdot \overrightarrow{ds}$ ( )

(d) $\oint \vec{E} \cdot \overrightarrow{ds}$ ( )

4. The speed of light in free space is

(a) $\frac{1}{\sqrt{2\varepsilon_0 \mu_0}}$ ( )

(b) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ ( )

(c) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ ( )

(d) $\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ ( )

5. When the phase angle between the E_x and E_y components is 0° or 180°, the polarization is

(a) elliptical ( )

(b) circular ( )

(c) linear ( )

(d) perpendicular ( )

6. In a conductor, the phase difference between displacement and conduction current is

(a) $\frac{\pi}{4}$ ( )

(b) $\frac{\pi}{2}$ ( )

(c) π ( )

(d) zero ( )

7. The momentum of charged particle, $\vec{p}$ in an electromagnetic field is given by

(a) $\vec{p} = m\vec{a} + q\vec{v}$ ( )

(b) $\vec{p} = m\vec{v} + q\vec{A}$ ( )

(c) $\vec{p} = mc^2 + q\vec{B}$ ( )

(d) $\vec{p} = m\vec{a} - q\vec{v}$ ( )

8. 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 ( )

9. The law governing the distribution of radiant energy over wavelength for a black body at fixed temperature is referred to as

(a) Kirchhoff's law ( )

(b) Planck's law ( )

(c) Wien's formula ( )

(d) Lambert's law ( )

10. What is needed to achieve population inversion?

(a) To excite most of the atoms ( )

(b) To bring most of the atoms to ground state ( )

(c) To achieve stable condition ( )

(d) To reduce the time of production of laser ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer the following questions : 3×5=15

UNIT—I

1. Deduce the integral form of Faraday's law of electromagnetic induction.

OR

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

UNIT—II

3. Show that the electromagnetic waves are transverse in nature.

OR

4. In an electromagnetic wave in empty space whose electric field is given by $\vec{E} = 60\,\hat{x}e^{-i(10^8 t+4z)}$. Determine the magnetic field of the wave.

UNIT—III

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

OR

6. Using Maxwell's equations, show that an electromagnetic wave is damped inside a conducting medium.

UNIT—IV

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

OR

8. Derive an equation for scalar potential of magnetic dipole.

UNIT—V

9. State and prove Kirchhoff's law for radiation.

OR

10. What do you mean by optical pumping?

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer the following questions : 10×5=50

UNIT—I

1. *(a)* Prove that, Faraday's law of electromagnetic induction can be expressed in differential form and give the physical meaning of the equation.

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

(c) A field of 0·02 tesla acts at right angles to a coil of area 0·01 square-meter with 50 turns. The coil is removed from the field in $\frac{1}{10}$th of a second. Find the e.m.f. produced in it.

OR

2. *(a)* Discuss the reason which led Maxwell to modify Ampere's law by introducing the concept of displacement current. Hence derive the new relation.

(b) 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.

UNIT—II

3. *(a)* Deduce the general equations for electromagnetic wave satisfied by $\vec{E}$ and $\vec{B}$ in free space. Write the solutions for it. 6

(b) What do you know about momentum and radiation pressure of electromagnetic wave? 4

OR

4. *(a)* Derive necessary equation to define the Poynting vector and also explain the Poynting theorem. 6

(b) If a 500 watt laser beam is concentrated by a lens into a cross-sectional area of 10^{-10} m^2, find the value of Poynting vector and the amplitude of electric field. 4

UNIT—III

5. Deduce the expression for reflection and transmission coefficients of an electromagnetic wave travelling from one dielectric media to another dielectric media at normal incidence. 10

OR

6. *(a)* What is the total internal reflection of an electromagnetic wave? Show that the wave is totally reflected back at total internal reflection. 4+2=6

(b) Calculate the skin depth for an electromagnetic wave of wavelength 3 m (in free space) in a conducting medium of conductivity $\sigma = 6 \times 10^7\ \Omega^{-1}\ m^{-1}$ and permeability $\mu = 4\pi \times 10^{-7}$ H/m. 4

UNIT—IV

7. *(a)* Deduce Maxwell's equations in terms of vector and scalar potentials and express them using D'Alembertian operator. 6

(b) Obtain the expression of Lorentz force in terms of vector and scalar potentials. 4

OR

8. Discuss the transformation of electromagnetic wave by using Lorentz gauge transformation and explain how the Lorentz gauge is used to explain the wave theory. 6+4=10

UNIT—V

9. Starting from quantum hypothesis, establish Planck's radiation law. Deduce Wien's law from Planck's radiation law. 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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Student's Copy

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