Student's Copy

2025

(NEP—2020)

(5th Semester)

PHYSICS (MAJOR3/MINOR)

(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 Gaussian surface for finding the electric field due to a uniformly charged sphere is

   (a) cylinder ( )

   (b) sphere ( )

   (c) cube ( )

   (d) any closed surface ( )

2. Laplace's equation is valid

(a) in regions with no free charge ( )

(b) in conductors ( )

(c) inside dielectrics only ( )

(d) always ( )

3. The relative permittivity ε_r is given by

(ε_0 is the free space permittivity, χ_e is the susceptibility, and K is the dielectric constant)

(a) $1+\chi_e$ ( )

(b) $1-\chi_e$ ( )

(c) $\frac{\chi_e}{\varepsilon_0}$ ( )

(d) $K-1$ ( )

4. The continuity equation expresses

(a) conservation of momentum ( )

(b) conservation of charge ( )

(c) conservation of energy ( )

(d) conservation of angular momentum ( )

5. The displacement current density is

(a) $\varepsilon_0 \partial E / \partial t$ ( )

(b) $\mu_0 \partial E / \partial t$ ( )

(c) $\partial B / \partial t$ ( )

(d) σE ( )

6. The Coulomb gauge condition is

(a) $\vec{\nabla} \cdot \vec{A} = 0$ ( )

(b) $\vec{\nabla} \times \vec{A} = 0$ ( )

(c) $\vec{\nabla} \cdot \vec{E} = \rho / \varepsilon_0$ ( )

(d) $\vec{\nabla} \cdot \vec{A} + (1 / c^2) \partial \varphi / \partial t = 0$ ( )

7. Expression for electric field of a monochromatic plane wave of amplitude E_0, frequency ω, travelling in the negative x direction and polarized in the z direction is

(a) $E_0 e^{i(-kx - \omega t)} \hat{z}$ ( )

(b) $E_0 e^{i(kz - \omega t)} \hat{x}$ ( )

(c) $E_0 e^{i(-kz - \omega t)} \hat{x}$ ( )

(d) $-E_0 e^{i(kz - \omega t)} \hat{x}$ ( )

8. The direction of propagation of EM wave is given by

(a) $\vec{E} \times \vec{B}$ ( )

(b) $\vec{E} \cdot \vec{B}$ ( )

(c) $\vec{E} + \vec{B}$ ( )

(d) $\vec{E} - \vec{B}$ ( )

9. For a light wave travelling from one dielectric medium to another dielectric medium, the relation between the magnitudes of the incident (k_I), reflected (k_R) and transmitted (k_T) wave vectors is (if v_1 and v_2 are the velocities of the light wave in the first and second medium)

(a) $k_I = k_T = \frac{v_1}{v_2} k_R$ ( )

(b) $k_I = k_R = \frac{v_2}{v_1} k_T$ ( )

(c) $k_I = k_R = k_T$ ( )

(d) $k_I \neq k_R = \frac{v_1}{v_2} k_T$ ( )

10. For a light wave travelling from air into glass medium with refractive index 1·5 at normal incidence, the reflection coefficient is

(a) 0·025 ( )

(b) 0·40 ( )

(c) 0·96 ( )

(d) 1 ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 25)

Answer *five* questions, taking at least *one* from each Unit : 5×5=25

UNIT—I

1. What are polarization vector and displacement vector? Obtain the relation between displacement vector and polarization vector.

2. Give the statement of Gauss's law. Obtain its differential form.

UNIT—II

3. Explain how the Ampere's law in differential form was modified by Maxwell.

4. Show that electric and magnetic fields can propagate like a wave in free space and dielectrics.

UNIT—III

5. Show that refractive index of a dielectric medium is equal to the square root of the dielectric constant.

6. Write the expression for wave impedance of a free space. Calculate its value if permittivity of free space is $8 \cdot 85 \times 10^{-12} \mathrm{F/m}$.

UNIT—IV

7. From Fresnel's equation, obtain Brewster's law.

8. What do you mean by total internal reflection? Under what condition would this occur?

(SECTION : C—DESCRIPTIVE)

(*Marks* : 40)

Answer *four* questions, taking *one* from each Unit : 10×4=40

UNIT—I

1. (*a*) Using Gauss's law, find the electric field at a point (*i*) inside and (*ii*) outside of a uniformly charged solid sphere of radius R and total charge Q. 2+3=5

   (*b*) Explain the process of dielectric polarization for both polar and non-polar dielectrics. Deduce Gauss's law in dielectric medium. 2+3=5

2. (*a*) An infinite plane carries a uniform surface charge density σ. Find its electric field using Gauss's theorem. 3

   (*b*) Show that the capacitance of a parallel-plate capacitor is $\frac{A\varepsilon_0}{d}$, if A is area of the parallel plate, d is the separation between the plates and ε_0 is the permittivity of free space. Further deduce the capacitance if (*i*) the space between the parallel-plate capacitor is filled with dielectric having dielectric constant ε_r and (*ii*) a dielectric having dielectric constant ε_r and thickness t is inserted between the plates (here $< d$). 7

UNIT—II

3. Write all the four Maxwell's equations in integral form. Using these equations, deduce the four boundary conditions. 2+8=10

4. Starting from Maxwell's equations, derive Poynting's theorem and clearly explain the physical meaning of each term in the resulting equation. 7+3=10

UNIT—III

5. For an electromagnetic wave propagating inside a conductor, show that the wave number is complex and deduce expressions for the real and imaginary parts of the wave number. Also obtain the expressions for skin depth in both poor conductor and good conductor. 7+3=10

6. Write down Maxwell's equations in linear isotropic dielectric medium. From these equations, show that electric and magnetic fields can propagate as a wave inside such medium. Further deduce the transverse nature of the electromagnetic wave and obtain the ratio of the amplitudes of electric and magnetic fields in the medium. 2+4+4=10

UNIT—IV

7. Obtain Fresnel equations for reflection and refraction of electromagnetic waves at a plane boundary separating two media when the incident wave is polarized with $\vec{E}$ perpendicular to the plane of incidence. 10

8. Consider a monochromatic plane wave travelling from linear isotropic dielectric medium to a conductor and entering the conductor at normal incidence. Write the expressions for incident wave, reflected wave and transmitted wave. Using boundary conditions, deduce the reflection coefficient and transmission coefficient values. Write the interpretations of your results. 3+6+1=10

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