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63/1 (SEM–6) CC13/PHYHC6136

2024

PHYSICS

Paper : PHYHC6136

(Electromagnetic Theory)

Full Marks : 60

Pass Marks : 24

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Choose the correct option ***(any five)*** from the following : 1×5=5

   (a) The displacement current density is equal to

   (i) $\vec{J}$

   (ii) $\frac{\partial \vec{D}}{\partial t}$

   (iii) $\vec{H}$

   (iv) $\frac{\partial Pav}{\partial t}$

Contd.

(b) The energy stored per unit volume in an electric field is

(i) $\frac{1}{2}\mu H^2$

(ii) $\frac{1}{2}\left(\varepsilon H^2 + \mu H^2\right)$

(iii) $\frac{1}{2}\varepsilon E^2$

(iv) $\varepsilon E^2 + \mu H^2$

(c) For vertical incident, the critical angle at which the electromagnetic wave reflects back to the earth from ionosphere is

(i) $9\sqrt{N_{max}}$

(ii) $1 - 9\sqrt{N_{max}}$

(iii) $9\sqrt{N_{max}}\sec\phi$

(iv) $9\sqrt{N_{max}}\cos\phi$

where N_{max} is the maximum number of free electrons per unit volume.

(d) A plane electromagnetic wave of frequency w is incident normally on an air-dielectric interface. The dielectric is homogeneous, isotropic and non-magnetic. Its refractive index is μ. The reflectance (R) and transmittance (T) at the interface is given by

(i) $R = \left[\frac{n-1}{n+1}\right]^2, T = \frac{4n}{(n+1)^2}$

(ii) $R = \left[\frac{n-1}{n+1}\right], T = \frac{2}{(n+1)^2}$

(iii) $R = \left[\frac{n-1}{n+1}\right]^3, T = \frac{4n^3}{(n+1)^3}$

(iv) $R = \left[\frac{n-1}{n+1}\right]^2, T = \frac{4n^2}{n+1}$

(e) After emerging out from an anisotropic crystal plate, when *e*-wave and *o*-wave overlap on each other, they produce

(i) Interference

(ii) Diffraction

(iii) Polarization

(iv) Un-Polarization

(f) The Path difference of *e*-wave and *o*-wave emerging out from a quarter wave plate is

(i) $\frac{\lambda}{2(\mu_o - \mu_e)}$

(ii) $\frac{\lambda}{2(\mu_e - \mu_o)}$

(iii) $\frac{\lambda}{4(\mu_o - \mu_e)}$

(iv) $\frac{\lambda}{2(\mu_e - \mu_o)}$

(g) The electromagnetic wave used in Laurent's half-shade polarimeter is

(i) Monochromatic Plane Polarized wave

(ii) Monochromatic un-polarized wave

(iii) Chromatic Plane Polarized wave

(iv) Chromatic un-Polarized wave

(h) The product of phase velocity and group velocity of electromagnetic wave is equal to

(i) Square of the velocity of electromagnetic wave

(ii) Velocity of electromagnetic wave

(iii) Exceeds the velocity of electromagnetic wave

(iv) Less than the velocity of electromagnetic wave

(i) The basic Principle of Optical fibre is based on

(i) reflection on electromagnetic wave

(ii) refraction of electromagnetic wave

(iii) scattering of electromagnetic wave

(iv) total internal reflection of electromagnetic wave

(j) A single mode fibre

(i) has a smaller core diameter and supports only one mode of Propagation.

(ii) has a smaller core diameter and supports a number of modes of Propagation.

(iii) has a longer core diameter and supports only one mode of Propagation.

(iv) has a longer core diameter and supports a number of modes of Propagation.

2. Answer the following questions : ***(any five)*** 2×5=10

(a) What is Lorentz gauge condition ? How it can be converted to a Coulomb gauge ?

(b) How will you be confirmed that electromagnetic wave is transverse in nature ?

(c) What is intrinsic impedance of free space ?

(d) What is internal reflection of electromagnetic wave ? Suppose a monochromatic electro-magnetic wave is incident on the interface from a denser medium to a rarer medium. At what condition the reflected wave will pass through the boundary line of the two media ?

(e) Calculate the speed of ordinary and extra-ordinary electromagnetic waves in calcite crystal.

(Given, $\mu_o = 1{\cdot}658$ and $\mu_e = 1{\cdot}486$)

(f) Explain elliptical polarisation of electromagnetic wave.

(g) A 200 *mm* long tube containing 48 cm^3 of sugar solution produces an optical rotation of 11° when placed in a saccharimeter. If the specific rotation of sugar solution is 66°, calculate the quantity of sugar contained in the tube.

3. Answer the following questions : ***(any five)*** 5×5=25

(a) Define electromagnetic wave. Write down the physical significance of Maxwell's equation. 1+4=5

(b) Show that, for an isotropic dielectric medium, the velocity of electromagnetic wave is

$$\frac{1}{\sqrt{\mu\varepsilon}}$$

where, μ and ε are refractive index and permittivity of the medium.

(c) "Skin depth is a measure of the distance of penetration of an electromagnetic wave into a good conductor before its magnitude drops to $\frac{1}{e}$ times its value at the surface." Justify.

(d) Prove that

$\mu = \sqrt{\varepsilon_r}$ where μ and ε_r are the refractive index and relative permittivity of material.

(e) Show that the reflected electromagnetic wave at the interface of two dielectrics is plane polarized, when the angle of incident is equal to Brewster angle, i.e., $tan^{-1}\left(\frac{\mu_2}{\mu_1}\right)$, where μ_1 and μ_2 are the corresponding refracted indices of the two dielectrics.

(f) Define an anisotropic crystal. Distinguish between uniaxial and biaxial crystals with examples. 1+4=5

(g) (i) What is a half-waveplate ? 3

(ii) Plane polarized electromagnetic wave of wavelength 5000Å is incident on a piece of quarter cut parallel to the axis. Find the least thickness for which the ordinary and extra-ordinary waves combine to form plane polarized wave (Given, $\mu_o = 1{\cdot}5533$, $\mu_e = 1{\cdot}5442$) 2

(h) Write Fresnel's assumption on optical rotation. Explain clearly the left hand and right hand circularly polarized vector rotating in opposite direction. 2+3=5

(i) What do you mean by numerical aperture of an optical fibre ? Calculate the total number of internal reflection at an acceptance angle 30° for an optical cable of length one meter and radius 25μm. (Given refractive index of the core is 1·50). 2+3=5

4. Answer the following questions : ***(any two)*** 10×2=20

(a) (i) Define Poynting vector. Derive an expression of it and explain its physical significance. 1+3+2=6

(ii) In an electromagnetic wave the magnitude of electric field vector is 60π volt/meter. Determine the magnitude of Poynting vector. (Given velocity of EM wave = 3×10^8 *m/sec*,

$$\frac{\mu_0}{4\pi}=1\times10^{-7} \text{ Henry/meter} \quad 4$$

(b) Derive Fresnel equations for reflection and refraction (Perpendicular and Parallel Polarization) for electromagnetic wave at the interface of isotropic linear media. 5+5=10

(c) (i) Explain the phenomenon of double refraction of electromagnetic wave in uniaxial crystal. 2

(ii) How a Nicol Prism can be used as a polarizer ? 5

(iii) A Partially polarized electromagnetic wave is passed through a Nicol prism. In 90° rotation of the prism, the intensity changes from I_{max} to 0·3 I_{max}. Find the degree of polarisation. 3

(d) Define TE and TM modes of an waveguide. Derive the equations of TE mode of a planar waveguide. 4+6=10
