2024
B.A./B.Sc.
Sixth Semester
CORE – 13
PHYSICS
Course Code: PHC 6.11
(Electromagnetic Theory)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five *questions, taking* one *from each unit.*

UNIT–I

1. (a) Evaluate the gauge transformation in electrodynamics to show that the d'Alembertian plays the same role in four dimensions as the Laplacian plays in classical mechanics. 9
   (b) Establish the Maxwell's fourth equation by using the concept of the equation of continuity. 5

2. (a) A sphere of radius 2m is uniformly charged in free space throughout its volume with a volume charge density of 2 C/m^3 and absolute permittivity of 8.854×10^{-12} farad/metre. Determine the electric field at a distance (r) from the centre of the sphere when
   (i) $r <$ radius (ii) $r >$ radius. 3+3=6
   (b) Calculate the magnitude of poynting vector at the surface of the sun of radius 7×10^8 m, if the power radiated by the sun is 3.8×10^{26} watts. 3
   (c) Find the surface charge density on the surface of the earth with a field of 300 Vm^{-1}? 4
   (d) What is the physical significance of Maxwell's fourth equation? 1

UNIT–II

3. (a) Show that electromagnetic wave travel at the speed of light. 5

   (b) Evaluate the impedance of a medium during the propagation of an electromagnetic wave from the Maxwell's equations. 9

4. (a) An electromagnetic wave polarised along the *x*-direction is propagating in vacuum as described by the equation (in SI unit)

   $$E = \hat{x}E_0 \exp\left[i(wt - 600y + 800z)\right]$$

   (i) Determine the wavelength and frequency of the wave.

   (ii) Compute the angle that the κ vector makes with the *y*-axis.

   (iii) Establish that the electromagnetic wave is transverse.

   2+1+1=4

   (b) Calculate the skin depth for electromagnetic wave of frequency 100 and 100 MHz for copper of conductivity 6.25×10^7 mho/m and the permittivity nearly equal to 8.854×10^{-12} farad/metre after evaluating its conductivity. 5

   (c) Show that fresh water with conductivity of 10^{-3} ohm/m and permittivity nearly equal to $80 \times 8.854 \times 10^{-12}$ farad/metre can behave as a good conductor for frequency at 10 Hz and as a poor conductor at 10 GHz. 5

UNIT–III

5. (a) A plane electromagnetic wave polarised along the *y*-axis is propagating along the positive *x*-direction and incident at normal incidence at the interface of two media. Evaluate that the wave obeys the law of conservation of energy. 7

   (b) Establish the law of reflection and the law of refraction for an electromagnetic wave propagating at oblique incidence. 7

6. (a) An electromagnetic wave traversing in air and polarised along the *y*-axis has its peak value of electric field as 5 V/m incident normally on a dielectric with refractive index of 2.5 and free space wavelength of 6×10^{-7} m.

(i) Compute the amplitude of the of the reflected and transmitted field vector along with its corresponding magnetic field vector.

(ii) Show that the amplitude of the magnetic vector associated with the transmitted wave is greater than that of the incident wave.

(iii) Calculate the Poynting vectors associated with the incident, reflected and transmitted wave.

(iv) Determine the transmission and reflection coefficient.

6+2+2+2=12

(b) Determine the critical angle for a glass-air interface, where the refractive index of glass is 1.5 and air is 1. 2

UNIT–IV

7. (a) Justify that the existence of polarization property is a direct consequence of light being a transverse wave. 4

(b) Evaluate the action of a Nicol prism along with construction and necessary figure. 4+2+1=7

(c) Explain dichroism. 3

8. (a) Evaluate how light from ordinary light source is unpolarized? 4

(b) If the refractive index for ordinary light in the case of calcite and Canada balsam are 1.658 and 1.550 respectively, calculate the maximum possible inclination with the Canada balsam surface so that the ordinary ray is still quenched. 3

(c) Calculate the thickness of quarter wave plate for light of wavelength 5893 Å if the refractive index for ordinary and extra ordinary ray are 1.544 and 1.553 respectively. 3

(d) A beam of linearly polarised light is changed into circularly polarised light by passing it through a slice of crystal of thickness 0.003 cm. Compute the difference in refractive indices of the two rays in the crystal for a wavelength of 6×10^{-7} m, assuming this to be the minimum thickness that will produce the effect. 4

UNIT–V

9. (a) What is the principle of the propagation of light signals in optical fibre? 1

(b) Evaluate the two types of optical fibre based on the modes of light propagation 3+4=7

(c) State the laws of the rotation of the plane of polarization. 3

(d) A tube of length 150 mm tube containing sugarcane solution of specific rotation 66° shows optical rotation. Calculate the strength of the solution. 3

10. (a) Establish the Fresnel's theory of optical rotation. 7

(b) A 20 cm long tube containing sugar solution is placed between crossed Nicols and illuminated by light of wavelength of 6000 Å. If the specific rotation of is 60 degrees and the optical rotation is 12 degrees, calculate the strength of the solution. 4

(c) A step index fibre is with a core of refractive index 1.56 and cladding of refractive index 1.50. Calculate the intermodal dispersion per kilometer of length of the fibre and the total dispersion in a 10 km length of the fibre. 3