May 2025
M.Sc.
Second Semester
CORE – 05
PHYSICS
Course Code: MPHC 2.11
(Electrodynamics)

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

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

UNIT–I

1. (a) Using Maxwell's equations, derive the expression for inhomogeneous wave equation in terms of electromagnetic potentials $\vec{A}$ and φ. 6
   (b) Show that the electric and magnetic field are invariant under gauge transformation. 5
   (c) The vector potential $\left(\vec{A}\right)$ due to a magnetic moment *m* at a point *r* is given by $\vec{A} = \frac{\vec{m} \times \vec{r}}{r^3}$. If magnetic moment is directed along the positive *z*-axis. Find the magnetic field at point *r* of the *x*-component. 3

2. (a) Deduce the Laplace equation in spherical coordinate and obtain its solutions. 6
   (b) Discuss Green's reciprocity theorem. 5
   (c) The electrostatic potential is given by $\varphi = a - b(x^2 + y^2)$ where *a* and *b* are constants. Find the charge density in the region. 3

UNIT–II

3. Show that for an electromagnetic wave in a dispersive medium, $n = 1 + A\left[1 + \frac{B}{\lambda^2}\right]$ where *A* is coefficient of fraction and *B* the coefficient of dispersion. 14

4. (a) An electromagnetic wave with $\vec{E}(z,t) = E_o \cos(\omega t - kz)\hat{\imath}$ is travelling in free space and crosses a disc of radius *m* placed perpendicular to the *z*-axis. If $E_o = 90\text{V}m^{-1}$. Find the average intensity or power crossing the disc along the *z*-direction. 3

(b) The frequency dependence dielectric constant of a material is given by $\varepsilon_r = 1 + \dfrac{A}{\omega_o^2 - \omega^2 - i\omega\gamma}$, where A is a positive constant, ω_o the resonant frequency, and γ the damping coefficient. Show that for an electromagnetic wave of angular frequency $\omega < \omega_o$, if $\dfrac{\gamma}{\omega_o} \ll 1$, there is negligible absorption of the wave. 4

(c) Discuss the reflection and transmission coefficient of a plane monochromatic electromagnetic waves at oblique incidence. 7

UNIT–III

5. (a) Derive the expression for an electromagnetic wave travelling in a rectangular waveguide. 10

(b) Find the radius and guide wavelength in an air-filled circular waveguide for the dominant mode at $f = 30\,\text{GHz} = 1.5 f_c$. Will TM_{11} mode propagate at this mode? 4

6. (a) What is waveguide? Deduce the expression for the electric and magnetic field in a waveguide. 8

(b) For TE_{01} mode $E_x = j\dfrac{\omega\mu\pi}{bh^2} H_o \sin\left(\dfrac{\pi}{b} y\right) e^{-\gamma}, E_y = 0.$ Find the average, total Poynting vector and the average power transmitted across the guide surface where $x = 0$ to $x = a$ and $y = 0$ to $y = b$. 6

UNIT–IV

7. (a) Deduce the retarded potential solution of an inhomogeneous wave equations. 7

(b) Derive the Abraham-Lorentz formula. 7

8. (a) What is radiation? Deduce the expression for radiated power of an oscillating electric dipole. 8
   (b) Write a short note on Bremsstrahlung. 6

UNIT–V

9. (a) Derive electric field due to a uniformly moving charge by using relativistic transformation. 7
   (b) A particle with charge q moves in an inertial system S with the velocity $u = (a, a, a)$ in a homogeneous magnetic field $B = (B, 0, 0)$. Consider S' be an inertial system which moves relative to S with velocity $v_z = v\hat{e}_z = \text{constant}$. Find the force acting on the particle in S and S' frame. 4
   (c) Show that the three-dimensional volume element $dxdydz$ is not invariant, but the four-dimensional volume element is invariant under Lorentz transformation. 3

10. (a) Find an expression for field-tensor tensor and explain its importance. 7
   (b) What is space time interval? Discuss the physical significance of timelike, spacelike, and lightlike. 7