

Fifth Semester B.E. Degree Examination, July/August 2021

Electromagnetic Waves

Time: 3 hrs.

Max. Marks: 100

Note: Answer any FIVE full questions.

- 1
 - a. Point charges of 50nc each are located at $A(1, 0, 0)$, $B(-1, 0, 0)$, $C(0, 1, 0)$ and $D(0, -1, 0)$. Determine the total force on the charge at A. Also, find \vec{E} at 'A'. (07 Marks)
 - b. Two point charges, $5\mu\text{C}$ and $-3\mu\text{C}$ are placed along a straight line 10m apart. Determine the location of third charge, $4\mu\text{C}$ such that it is subjected to no force. (07 Marks)
 - c. Derive an expression for electric field intensity at a point due to an infinite sheet charge, $\rho_s \text{ C/m}^2$. Compare the nature of this field with that of infinite line charge. (06 Marks)
- 2
 - a. Given the two points $C(-3, 2, 1)$ and $D(5, 20^\circ, -70^\circ)$, find the spherical coordinates of 'C' and Cartesian coordinates of 'D'. Also find the distance from 'C' to 'D'. (07 Marks)
 - b. A uniform line charge, infinite in extent, with the density 34nc/m is located at $x = -3\text{m}$ and $z = 5\text{m}$ in free space. Find \vec{E} at $P(1, 12, 4)\text{m}$. (07 Marks)
 - c. Find the total charge within each of the indicated volume :
 - i) $0 \leq \rho \leq 0.1$, $0 \leq \phi \leq \pi$, $2 \leq z \leq 4$ and $\rho_v = \rho^2 z^2 \sin(0.6\phi)$
 - ii) Universe : $\rho_v = \frac{e^{-2r}}{r^2}$. (06 Marks)
- 3
 - a. A cube of side 2m is centred at the origin with edges parallel to the coordinate axes of the rectangular coordinate system. If $\vec{D} = 10 \frac{x^3}{3} \hat{a}_x \text{ C/m}^2$, find the volume charge density. Also, find the total charge enclosed by the cube. (06 Marks)
 - b. A vector field is given by $\vec{A} = 30e^{-r} \hat{a}_r - 2z \hat{a}_z$, verify the divergence theorem for the volume enclosed by $r = 2$, $z = 0$ and $z = 5$. (08 Marks)
 - c. Determine the electric field intensity everywhere due to a spherical volume charge of density, $\rho_v \text{ C/m}^3$ using Gauss's law. Also, sketch E as a function of distance. (06 Marks)
- 4
 - a. Calculate the work done in moving a 4C charge from $B(1, 0, 0)$ to $A(0, 2, 0)$ along the path $y = 2 - 2x$, $z = 0$ in the field $\vec{E} = 5x \hat{a}_x + 5y \hat{a}_y \text{ V/m}$. (07 Marks)
 - b. State and explain the continuity equation of current. Also, mention its physical significance. (08 Marks)
 - c. Given the potential field, $V = 2x^2y - 5z$ and a point $P(-4, 3, 6)$, find the numerical values of the following quantities at point, P : i) Electric potential ii) Electric field intensity \vec{E} iii) the direction of \vec{E} iv) electric flux density, \vec{D} v) volume charge density ρ_v . (05 Marks)
- 5
 - a. Using the Laplace's equation, derive an expression for capacitance per unit length of a coaxial cable using the following boundary conditions : $V = V_0$ at $r = a$, and $V = 0$ at $r = b$, $b > a$. (08 Marks)
 - b. Determine \vec{H} at $(0.4, 0.3, 0)$ in the field of 8A filamentary current directed inward from infinity to the origin on the positive x -axis and then outward to infinity along the y -axis. (08 Marks)
 - c. State and explain the Stoke's theorem. (04 Marks)

- 6 a. Given the potential field $V = (Ar^4 + Br^{-4}) \sin(4\phi)$, show that $\nabla^2 V = 0$. Also find A and B such that $V = 100$ volts and $|\vec{E}| = 500 \text{ V/m}$ at $p(1, 22.5^\circ, 2)$. (07 Marks)
- b. Evaluate both sides of the Stoke's theorem for the field, $\vec{H} = 6xy\hat{a}_x - 3y^2\hat{a}_y, \text{ A/m}$ and the rectangular path around the region $2 \leq x \leq 5, -1 \leq y \leq 1, z = 0$. Let the positive direction of $d\vec{S}$ be \hat{a}_z . (07 Marks)
- c. State the following and write the corresponding equations :
Biot Savart law, Ampere's law and Curl \vec{F} . (06 Marks)
- 7 a. Derive an expression for the force acting between two differential current elements. (04 Marks)
- b. Find the magnetization in a wire where i) $\mu = 1.8 \times 10^{-5} \text{ H/m}$, and $H = 120 \text{ A/m}$
ii) $\mu_r = 22$, there are 8.3×10^{28} atoms/ m^3 and each atom has a dipole moment of $4.5 \times 10^{-27} \text{ A-m}^2$ iii) $\beta = 300 \mu\text{T}$ and $\Psi_m = 15$. (08 Marks)
- c. A conducting filamentary triangle joins points A(3, 1, 1), B(5, 4, 2) and C(1, 2, 4). The segment AB carries a current of 0.2A in \hat{a}_{AB} direction. The magnetic field is $\vec{B} = 0.2\hat{a}_x - 0.1\hat{a}_y + 0.3\hat{a}_z \text{ T}$.
i) Find the force on segment BC
ii) The torque on the loop about an origin at 'A'
iii) The torque on the loop about an origin at 'C'. (08 Marks)
- 8 a. Obtain the torque on a square loop having the corners $(-2, -2, 0)$, $(2, -2, 0)$, $(2, 2, 0)$ and $(-2, 2, 0)$:
i) About the origin by $\vec{B} = 0.4\hat{a}_x \text{ T}$;
ii) About the origin by $\vec{B} = 0.6\hat{a}_x - 0.4\hat{a}_y \text{ T}$ and
iii) About $(4, 6, 8)$ by $\vec{B} = 0.4\hat{a}_x + 0.6\hat{a}_y - 0.7\hat{a}_z \text{ T}$. Take $I = 0.8 \text{ A}$. (08 Marks)
- b. Determine the boundary conditions for the magnetic field at the interface between two different magnetic materials. (06 Marks)
- c. Derive the Maxwell's equation from Faraday's law of electromagnetic induction. (06 Marks)
- 9 a. Let $\mu = 10^{-5} \text{ H/m}$, $\epsilon = 4 \times 10^{-9} \text{ F/m}$, $\sigma = 0$ and $\rho_v = 0$. Determine 'K' so that each of the following pair of fields satisfies Maxwell's equation :
i) $\vec{D} = 2x\hat{a}_x - 3y\hat{a}_y + 4z\hat{a}_z \text{ nC/m}^2$, $\vec{H} = Kx\hat{a}_x + 10y\hat{a}_y - 25z\hat{a}_z \text{ A/m}$
ii) $\vec{E} = (20y - kt)\hat{a}_x \text{ V/m}$, $\vec{H} = (y + 2 \times 10^6 t)\hat{a}_z \text{ A/m}$. (08 Marks)
- b. Explain the wave propagation in good conductors using the skin depth. (06 Marks)
- c. For a perfect dielectric medium, $\mu_r = 1$ and $\epsilon_r = 81$ at $f = 1 \text{ MHz}$. Determine attenuation constant, phase constant, propagation constant, wave length, phase velocity and intrinsic impedance for the medium. (06 Marks)
- 10 a. In a certain dielectric medium, $\epsilon_r = 5$, $\sigma = 0$ and displacement current density. $\vec{J}_d = 20 \cos(1.5 \times 10^8 t - \beta x)\hat{a}_y \mu\text{A/m}^2$. Determine the electric flux density and electric field intensity. (06 Marks)
- b. Explain the propagation of electromagnetic waves in free space. (08 Marks)
- c. State and prove Poynting theorem. (06 Marks)