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Fifth Semester B.E. Degree Examination, Jan./Feb. 2023
Electromagnetic Waves

Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1. a. The three vertices of a triangle are located at $A(6, -1, 2)$, $B(-2, 3, -4)$ and $C(-3, 1, 5)$. Find (i) $R_{AB} \times R_{AC}$ (ii) Area of triangle (04 Marks)
- b. Define Electric field intensity. Derive the expression for electric field intensity due to infinite line charge. (10 Marks)
- c. Given the electric flux density $\bar{D} = 0.3r^2 a_r \text{ nC/m}^2$ in free space.
 - (i) Find E at point $P(r = 2, \theta = 25^\circ, \phi = 90^\circ)$.
 - (ii) Find total charge within the sphere $r = 3$.
 - (iii) Find total electric flux leaving the sphere $r = 4$. (06 Marks)

OR

2. a. Four identical 3nC (nano Coulomb) charges are located at $P_1(1, 1, 0)$, $P_2(-1, 1, 0)$, $P_3(-1, -1, 0)$ and $P_4(1, -1, 0)$. Find the electric field intensity \bar{E} at $P(1, 1, 1)$. (10 Marks)
- b. Infinite uniform line charges of 5 nC/m lie along the (positive and negative) x and y axes in free space. Find \bar{E} at $P_A(0, 0, 4)$. (04 Marks)
- c. Define Coulomb's law. Make use of this to find the force on Q_1 . Given that the point charges $Q_1 = 50 \mu\text{C}$ and $Q_2 = 10 \mu\text{C}$ are located at $(-1, 1, -3)\text{m}$ and $(3, 1, 0)\text{m}$ respectively. (06 Marks)

Module-2

3. a. Explain Gauss law applicable to the case of infinite line charge and derive the relation used. (08 Marks)
- b. Evaluate both sides of the divergence theorem for the field $\bar{D} = 2xy a_x + x^2 a_y \text{ C/m}^2$ and the rectangular parallelepiped formed by the planes $x = 0$ and 1 , $y = 0$ and 2 and $z = 0$ and 3 . (08 Marks)
- c. Given the potential field $V = 2x^2y - 5z$ and point $P(-4, 3, 6)$. (i) Find potential V at P . (ii) Field intensity \bar{E} , (iii) Volume charge density ρ_v . (04 Marks)

OR

4. a. Compute the numerical value for $\text{div} \bar{D}$ at the point specified below:
 $\bar{D} = (2xyz - y^2) a_x + (x^2z - 2xy) a_y + x^2y a_z \text{ C/m}^2$ at $P_A(2, 3, -1)$ (04 Marks)
- b. Show that Electric field is a negative gradient of potential. (08 Marks)
- c. Let $E = y a_x \text{ V/m}$ at a certain instant of time and calculate the work required to move a 3c charge from $(1, 3, 5)$ to $(2, 0, 3)$ along the straight line segment joining
 - (i) $(1, 3, 5)$ to $(2, 3, 5)$ to $(2, 0, 5)$ to $(2, 0, 3)$
 - (ii) $(1, 3, 5)$ to $(1, 3, 3)$ to $(1, 0, 3)$ to $(2, 0, 3)$ (08 Marks)

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-3

- 5 a. Solve the Laplace's equation for the potential field in the homogenous region between the two concentric conducting spheres with radii 'a' and 'b' such that $b > a$, if potential $V = 0$ at $r = b$ and $V = V_0$ at $r = a$. Also find the capacitance between two concentric spheres. (10 Marks)
- b. State and explain Biot-Savart law applicable to magnetic field. (06 Marks)
- c. Calculate the value of vector current density in a rectangular coordinates at $P_A(2, 3, 4)$ if $\vec{H} = x^2z\vec{a}_y - y^2x\vec{a}_z$. (04 Marks)

OR

- 6 a. State and illustrate uniqueness theorem. (08 Marks)
- b. Define Stoke's theorem. Use this theorem to evaluate both sides of the theorem for the field $\vec{H} = 6xy\vec{a}_x - 3y^2\vec{a}_y$ 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 ds be \vec{a}_z . (12 Marks)

Module-4

- 7 a. Obtain the expression for magnetic force between differential current elements. (06 Marks)
- b. Derive the boundary conditions to apply to \vec{B} and \vec{H} at the interface between two different magnetic materials. (08 Marks)
- c. The point charge $q = 18\text{nC}$ has a velocity of 5×10^6 m/s in the direction $\vec{a}_v = 0.60\vec{a}_x + 0.75\vec{a}_y + 0.30\vec{a}_z$. Calculate the magnitude of the force exerted on the charge by the field,
- (i) $\vec{B} = -3\vec{a}_x + 4\vec{a}_y + 6\vec{a}_z$ mT
- (ii) $\vec{E} = -3\vec{a}_x + 4\vec{a}_y + 6\vec{a}_z$ kV/m
- (iii) \vec{B} and \vec{E} acting together

OR

- 8 a. Find the magnetization in a magnetic material, where
- (i) $\mu = 1.8 \times 10^{-5}$ H/m and $H = 120$ A/m
- (ii) $\mu_r = 22$, there are 8.3×10^{28} atoms/m³, and each atom has a dipole moment of 4.5×10^{-27} A.m²
- (iii) $B = 300 \mu\text{T}$ and $\chi_m = 15$. (06 Marks)
- b. Let permittivity be $5 \mu\text{H/m}$ in region A where $x < 0$ and $20 \mu\text{H/m}$ in region B, where $x > 0$. If there is a surface current density $\vec{K} = 150\vec{a}_y - 200\vec{a}_z$ A/m at $x = 0$, and if $\vec{H}_A = 300\vec{a}_x - 400\vec{a}_y + 500\vec{a}_z$ A/m. Compute
- (i) $|H_{tA}|$ (ii) $|H_{nA}|$ (iii) $|H_{tB}|$ (iv) $|H_{nB}|$ (08 Marks)
- c. State and explain Faraday's law of electromagnetic induction. (06 Marks)

Module-5

- 9 a. List and explain Maxwell's equations in point and integral form. (08 Marks)

- b. The time domain expression for the magnetic field of a uniform plane wave travelling in free space is given by,

$$H(z,t) = \bar{a}_y 2.5 \cos(1.257 \times 10^9 t - K_0 z) \text{ mA/m.}$$

Compute

- (i) The direction of wave propagation.
 - (ii) Operating frequency
 - (iii) Phase constant.
 - (iv) The time domain expression for electric field $E(z,t)$ starting from the Maxwell's equations.
 - (v) The phasor form of both the electric and magnetic field. (10 Marks)
- c. For silver the conductivity is $\sigma = 3 \times 10^6 \text{ S/m}$. At what frequency will the depth of penetration be 1 mm. (02 Marks)

OR

- 10 a. State and explain Poynting theorem and write the equation both in point and integral form. (08 Marks)
- b. Simplify the value of K to satisfy the Maxwell's equations for region $\sigma = 0$ and $\rho_v = 0$ if $\bar{D} = 10x\bar{a}_x - 4y\bar{a}_y + kz\bar{a}_z \text{ } \mu\text{C/m}^2$ and $B = 2a_y \text{ mT}$. (06 Marks)
- c. A plane wave of 16 GHz frequency and $E = 10 \text{ V/m}$ propagates through the body of salt water having constant $\epsilon_r = 100$, $\mu_r = 1$ and $\sigma = 100 \text{ s/m}$. Determine attenuation constant, phase constant, phase velocity and intrinsic impedance and depth and penetration. (06 Marks)
