FIELD THEORY
(ELEC 2204)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Ohm's law is obeyed by
(a) conduction current (b) convection current
(c) both conduction and convection current (d) none of them.

(ii) Which one is called as 'continuity equation'?
(a) $\nabla . E = -\frac{\partial \rho_v}{\partial t}$ (b) $\nabla . J = -\frac{\partial \rho_v}{\partial t}$
(c) $\nabla . V = -\frac{\partial \rho_v}{\partial t}$ (d) $\nabla . D = -\frac{\partial \rho_v}{\partial t}$

(iii) Skin depth is denoted by
(a) $1/\sqrt{\pi f \mu \sigma}$ (b) $\sqrt{\pi f \mu \sigma}$
(c) $1/\beta$ (d) α/β

(iv) Two identical coaxial circular coils carry the same current I but in opposite directions. The magnitude of magnetic field B at a point on the axis midway between the coils is
(a) zero (b) twice that produced by one coil
(c) the same as that produced by one coil (d) half that produced by one coil.

(v) Example of a scalar field is
(a) electric field intensity (b) magnetic field intensity
(c) electric potential (d) all of these.

(vi) Line integral of a magnetic field
(a) depends upon the path taken (b) independent of the path
(c) constant (d) none.

(vii) The magnetic boundary conditions are
(a) $H_{T1} = H_{T2}$, $B_{N1} = B_{N2}$ (b) $H_{T1} = H_{T2}$, $\mu_1 B_{N1} = \mu_2 B_{N2}$
(c) $\mu_1 H_{T1} = \mu_2 H_{T2}$, $B_{N1} = B_{N2}$ (d) None.

(viii) For an infinite sheet of current the magnetic field (B) above the sheet is
(a) μK/2 (b) μK (c) Zero (d) μJ.

(ix) A differential surface formed in cylindrical coordinates
(a) $d\rho\ dz$ (b) $(\rho d\phi)\ dz$ (c) $d\rho\ (\rho d\phi)$ (d) All

(x) For a lossless line propagation constant (γ) is given by
(a) $j\omega\sqrt{LC}$ (b) $j\omega\sqrt{\frac{L}{C}}$ (c) $j\omega\sqrt{C}$ (d) $j\omega\sqrt{L}$

Group- B

2. (a) Express the vector $A = rcos\emptyset\hat{a}_r + r\hat{a}_\theta$ into Cartesian coordinates. [(CO1)(Evaluate/HOCQ)]
(b) What is the gradient of a function G= $x^2 + y^3 + z^4$ at the point (4, 5, 6)? [(CO2)(Remember/LOCQ)]
(c) Examine that the vector $\overrightarrow{B} = (x + 5y)\hat{a}_x + (y - 3x)\hat{a}_y + (x - 2z)\hat{a}_z$ is solenoidal or not. [(CO2)(Analyse/IOCQ)]
5 + 4 + 3 = 12

3. (a) Transfer the vector $A = 3\hat{a}_x + 4\hat{a}_y + 5\hat{a}_z$ into cylindrical coordinates at point (2, π/2,-1). [(CO1)(Apply/IOCQ)]
(b) Prove Divergence Theorem for the vector field: $\vec{A} = (x^3 - y^3z^3)\hat{a}_x + (y^3 - x^3z^3)\hat{a}_y + (z^3 - y^3x^3)\hat{a}_z$ for a rectangular region defined by $0 \leq x \leq 2$, $0 \leq y \leq 3$, $0 \leq z \leq 4$. [(CO2)(Evaluate/HOCQ)]
6 + 6 = 12

Group - C

4. (a) Show the derivation of the electric flux density $\vec{D}$ with the help of Gauss's Law at any point due to point charge. [(CO3)(Understand/LOCQ)]
(b) Solve to get the charge density at $(5, \frac{\pi}{4}, 2)$ and the total charge enclosed by the cylinder of radius 2m with $-2 \leq Z \leq 2$ m. Given: $\vec{D} = z\rho Cos^3\phi\hat{a_z}$ C/m^2. [(CO3)(Apply/IOCQ)]
(c) Assume potential distribution in a given region of free space as $V = 10y^3 + 20x^2 + 5z^2$, to obtain $\overline{E}$ at (5,4,7). [(CO3)(Analyse/IOCQ)]
(d) Develop the relationship between electric field intensity and electric potential. [(CO3)(Create/HOCQ)]
3 + 3 + 3 + 3 = 12

5. (a) Explain the continuity equation. [(CO3) (Understanding/LOCQ)]
(b) Develop boundary conditions of electric field for dielectric-dielectric boundary. [(CO3)(Apply/IOCQ)]

(c) A homogeneous dielectric ($\varepsilon_r = 3.5$) fills region 1($x \leq 0$) while region 2 ($x \geq 0$) is free space. (i) If $\overrightarrow{D_1} = 12\hat{a}_x - 10\hat{a}_y + 4\hat{a}_z$ nC/m² find $\overrightarrow{D_2}$ (ii) If E_2 = 10V/m and $\theta_2 = 60°$, Determine E_1. Take $\theta_1$and $\theta_2$as the angles made by E_1 and E_2 respectively with the normal to the interface. [(CO3) (Evaluate/HOCQ)]

3 + 5 + 4 = 12

Group - D

6. (a) A conducting triangular loop carrying a current of 3 A is located close to an infinitely long straight conductor with a current of 10 A, as shown in Fig.1. Calculate the total force on the loop. [(CO4)(Evaluate/HOCQ)]

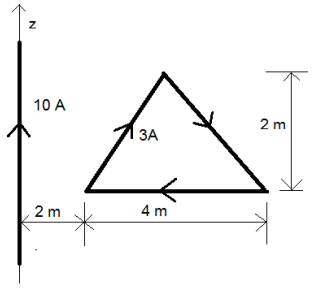

Fig.1

(b) Given that $B = 5\hat{a}_x - 5\hat{a}_z$wb/m, find the force it exerts on a 0.5 m conductor on the y-axis with a current 3 A in the $-\hat{a}_y$ direction. [(CO4)(Understand/LOCQ)]

(c) What is the physical significance of $\nabla . \overline{B}$ =0. [(CO4)(Understand/LOCQ)]

6 + 4 + 2 = 12

7. (a) A conducting filament carries current I from A $(0,0,a)$ to point B$(0,0,b)$. Show that at point P$(x,y,0)$,

$$H = \frac{I}{4\pi\sqrt{x^2+y^2}}\left[\frac{b}{\sqrt{x^2+y^2+b^2}} - \frac{a}{\sqrt{x^2+y^2+a^2}}\right]\hat{a}_{\emptyset}$$

[(CO4) (Understand/LOCQ)]

(b) Given that $\vec{H}_1 = \hat{a}_x + 8\hat{a}_y + 5\hat{a}_z$ A/m in region $y - x - 4 \leq 0$, where $\mu_1 = 6\mu_0$. Calculate $\vec{H}_2$ in region $-x - 4 \geq 0$, where $\mu_2 = 3\mu_0$. [(CO4)(Apply/IOCQ)]

6 + 6 = 12

Group - E

8. (a) Explain displacement current and displacement current density. [(CO5)(Evaluate/HOCQ)]

(b) What are the Maxwell's equations in integral form? [(CO5)(Remember/LOCQ)]

(c) A uniform plane wave in a good conductor with $\sigma = 10^{-3}$ S/m, $\varepsilon = 75\varepsilon_0$ and $\mu = \mu_0$is having a frequency of 9 kHz. Identify attenuation constant, phase constant, intrinsic impedance, wave length and velocity of wave. [(CO6) (Apply/IOCQ)]

3 + 3 + 6 = 12

9. (a) Prove that in lossless dielectrics the $\overrightarrow{E}$ and $\overrightarrow{H}$ of the plane wave are in time phase with each other. [(CO6) (Evaluate/HOCQ)]

(b) Explain what is skin depth and skin effect. [(CO6) (Understand /LOCQ)]

(c) Simplify the inconsistency in Ampere's law. Compare how it is rectified by Maxwell. [(CO5)(Analyze/IOCQ)]

(d) Assume a circuit conducting loop lies in the xy-plane as shown in Fig.2. The loop has a radius of 0.2m and resistance R = 5Ω. If $B = 80sin100t\hat{a}_z$ mWb/m^2, find the current. [(CO5)(Analyze/IOCQ)]

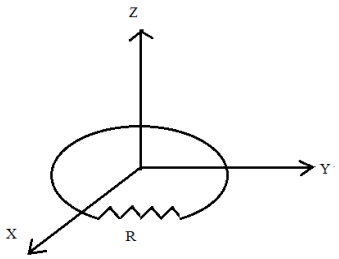

Fig.2

3 + 3 + 4 + 2 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	29.17	36.45	34.38

Course Outcome (CO):

After the completion of the course students will be able to

CO1: Apply knowledge of different co-ordinate systems for field analysis problems.

CO2: Apply different techniques of vector calculus to analyze electromagnetic fields to reach substantiated conclusions.

CO 3: Solve static electric field problems for different engineering applications by using vector calculus.

CO4: Solve static magnetic field problems for different engineering applications by using vector calculus.

CO5: Apply the knowledge of Maxwell's equation in solving wave propagation problems.

CO6: Understand and analyze the concepts of electromagnetic waves.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question