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) The magnetic field at any point on the axis of a current carrying circular coil will be
(a) perpendicular to the axis (b) parallel to the axis
(c) at an angle 45^0 with the axis (d) zero

(ii) The electromagnet has 50 turns and a current of 1 A flows through the coil. If the length of the magnet circuit is 200 mm, what is the magnetic field strength?
(a) 2500 AT/m (b) 250 AT/m (c) 25 AT/m (d) 2.5 AT/m.

(iii) The force between two long parallel conductors is inversely proportional to
(a) radius of conductors (b) current in one conductor
(c) product of current in two conductors (d) distance between the conductors.

(iv) A 300 mm long conductor is carrying a current of 10 A and is situated at right angles to a magnetic field having a flux density of 0.8 T; the force on the conductor will be
(a) 240 N (b) 24 N (c) 2.4 N (d) 0.24 N.

(v) According to Stoke's theorem
(a) $\int_S (\nabla \times \bar{A}) \cdot \bar{dS} = \oint_l \bar{A} \cdot \bar{dl}$ (b) $\int_V \bar{A}\, dV = \oint_S \bar{A} \cdot \bar{dS}$
(c) $\int_V (\nabla \cdot \bar{A})\, dV = \oint_S \bar{A} \cdot \bar{dS}$ (d) $\int_S \bar{A} \cdot \bar{dS} = \oint_l \bar{A} \cdot \bar{dl}$

(vi) _____ states that there can be no accumulation of charges at any point when currents are flowing.
Select the correct alternative:
(a) Continuity equation (b) Gauss's Law
(c) Boundary conditions (d) Faraday's Law

(vii) Which equation is derived from Ampere's Law among the following differential form of Maxwell's equations?
(a) $\nabla \cdot \bar{E} = \frac{\rho_v}{\varepsilon}$ (b) $\nabla \cdot \bar{B} = 0$ (c) $\nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}$ (d) $\nabla \times \bar{H} = \bar{J} + \frac{\partial \bar{D}}{\partial t}$

(viii) Which equation is named as differential point form of Gauss's law?

(a) $\rho_s = \nabla.\overline{B}$ (b) $\nabla.J = -\frac{\partial \rho_v}{\partial t}$ (c) $\rho_v = \nabla.\overline{D}$ (d) J=σE.

(ix) The intrinsic impedance, $\eta =$

(a) $E \times H$ (b) $u = \frac{1}{\sqrt{\mu\varepsilon}}$ (c) $\frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ (d) 0.

(x) The direction of propagation of electromagnetic wave is obtained from

(a) $\vec{E}.\vec{H}$ (b) $\vec{E} \times \vec{H}$ (c) $\vec{E} - \vec{H}$ (d) $\vec{E} / \vec{H}$.

Group- B

2. (a) Write the expressions for converting the spherical coordinates into Cartesian coordinates. *[(CO1)(Remember/LOCQ)]*

(b) Sketch the diagram of cylindrical coordinate system in xyz plane. *[(CO1)(Analyse/IOCQ)]*

(c) Write the expression of differential volume in spherical coordinate system. *[(CO1)(Remember/LOCQ)]*

(d) Examine that the vector $\overrightarrow{A} = yz\,\hat{a}_x + xyz\,\hat{a}_y + xy\,\hat{a}_z$ is solenoidal or not. *[(CO2)(Analyzing/IOCQ)]*

(e) Determine that the vector $\overrightarrow{C} = yz\,\hat{a}_x + xz\,\hat{a}_y + xy\,\hat{a}_z$ is irrotational or rotational. *[(CO2)(Evaluate/HOCQ)]*

2 + 2 + 2 + 3 + 3 = 12

3. (a) Given the point A(r=4, θ=25^0, φ = 120^0), determine the Cartesian coordinates of A. *[(CO1)(Evaluate/HOCQ)]*

(b) Convert the given rectangular coordinates A(2,3,1) into corresponding cylindrical coordinates. *[(CO1)(Evaluate/HOCQ)]*

(c) Find Divergence of the vector field at (2, 3, 4): $\vec{B} = (4xy)\hat{a}_x + (2xyz)\hat{a}_y + (2yz^2)\hat{a}_z$. *[(CO2)(Remember/LOCQ)]*

(d) Determine the gradient of a function V= $x^2 + y^3 + z^4$ at the point (1, 2, 3). *[(CO2)(Evaluate/HOCQ)]*

3 + 3 + 3 + 3 = 12

Group – C

4. (a) Show the derivation of the electric flux density $\vec{D}$ with the help of Gauss's Law for uniformly charged sphere of radius "a" if the Gaussian surface is a sphere of radius r ≥ a . *[(CO3)(Understand/LOCQ)]*

(b) Assume a point charge of 1.2 μC is located at r=0 to calculate D at r = 0.8 cm. *[(CO3)(Analyze/IOCQ)]*

(c) Assume a cube defined by 0< x < 2, 0 < y < 2, 0 < z < 2 is containing a volume charge density, $\rho_v = 20\,xyz\,\mu C/m^3$ and find the total outward electric flux from that cube. *[(CO3)(Analyze/IOCQ)]*

(d) Determine the electric field intensity and flux density at $(7, \frac{\pi}{2}, 0)$ if the potential is $V=\frac{5}{r^2} sin\,\theta\, cos\,\phi$. *[(CO3)(Create/HOCQ)]*

4 + 2 + 2 + 4 = 12

5. (a) Illustrate point form of Ohm's law. *[(CO3)(Understanding/LOCQ)]*
   (b) What is polarization in a dielectric? *[(CO3)(Remember/LOCQ)]*
   (c) Develop boundary conditions of electric field for conductor-dielectric boundary. *[(CO3)(Apply/IOCQ)]*
   (d) Two extensive homogeneous isotropic dielectrics meet on plane z=0. For $z > 0$, $\varepsilon_{r1} = 3$ for $z < 0$, $\varepsilon_{r2} = 2$. A uniform electric field $\overrightarrow{E_1} = 6\hat{a}_x + 2\hat{a}_y - 7\hat{a}_z$ kV/m exists for $z \geq 0$. Determine (i) $\overrightarrow{E_2}$ for $z \leq 0$ (ii) the angle $\overrightarrow{E_1}$ make with interface. *[(CO3)(Evaluate/HOCQ)]*

3 + 2 + 3 + 4 = 12

Group - D

6. (a) State Biot-Savart's Law. *[(CO4)(Remember/LOCQ)]*
   (b) Deduce the expression of magnetic field at any point due to a finite conductor. *[(CO4)(Analyse/IOCQ)]*
   (c) A steady current of I amps flows in a conductor bent in the form of a square loop of side a. Determine the magnetic field intensity at the centre of the loop. *[(CO4)(Evaluate/HOCQ)]*
   (d) State Ampere's Law. *[(CO4)(Remember/LOCQ)]*
   (e) Define Inductance of an Electrical circuit. *[(CO4)(Remember/LOCQ)]*

2 + 3 + 3 + 2 + 2= 12

7. (a) A solenoid with 200 turns is 300 mm long and 20 mm in diameter . If the current is 600 mA, determine (i) Inductance (ii) Energy stored in solenoid. *[(CO4)(Evaluate/HOCQ)]*
   (b) State two similarities and two differences between electric and magnetic circuits. *[(CO4)(Understand/LOCQ)]*
   (c) Classify the types of magnetic materials. *[(CO4)(Understand /LOCQ)]*
   (d) Deduce the expression of force between two current carrying conductors. *[(CO4)(Analyse/IOCQ)]*

2 + (2 + 2) + 3 + 3 = 12

Group – E

8. (a) Determine the conduction and displacement current densities in a material having conductivity of 10^{-2} S/m and $\varepsilon_r = 3.5$ if the electric field in the material is $E = 5 \times 10^{-6}(sin9) \times 10^9 t$ V/m. *[(CO5)(Evaluate/HOCQ)]*
   (b) What are the Maxwell's equations in integral form? *[(CO5)(Remember/LOCQ)]*
   (c) Identify the attenuation constant, phase constant, propagation constant, wavelength, skin depth and velocity of $\vec{E} = (18e^{-0.05x} Cos(3 \times 10^8 t - 4x)\hat{a}_z$ V/m. *[(CO6)(Apply/IOCQ)]*

3 + 3 + 6 = 12

9. (a) Develop the expressions of different parameters associated with a plane wave propagating in free space. *[(CO6)(Create/HOCQ)]*

   (b) Calculate the skin depth, δ and propagation constant at a frequency 2 MHz in aluminium where conductivity = 35 Ms/m and $\mu_r = 1$. *[(CO6)(Analyze/IOCQ)]*

   (c) What is Poynting's theorem? *[(CO6)(Remember/LOCQ)]*

   (d) Develop the solution of the inconsistency in Ampere's law.

[(CO5)(Apply/IOCQ)]

3 + 1.5 + 1.5 + 6 = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	34.9	32.81	32.29

Course Outcome (CO):

After the completion of the course students will be able to

1. Apply knowledge of different co-ordinate systems for field analysis problems.
2. Apply different techniques of vector calculus to analyze electromagnetic fields to reach substantiated conclusions.
3. Solve static electric field problems for different engineering applications by using vector calculus.
4. Solve static magnetic field problems for different engineering applications by using vector calculus.
5. Apply the knowledge of Maxwell's equation in solving wave propagation problems.
6. Understand and analyze the concepts of electromagnetic waves.

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