ELECTROMAGNETIC FIELD THEORY
(ELE2104)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) If y=10 in rectangular coordinate system, then the value of θ in cylindrical coordinate system is
(a) 90° (b) 45°
(c) 30° (d) 20°

(ii) If x = 3, y = 4 and z = 5, then the value of *r* in spherical coordinate system is
(a) 7.07 (b) 5
(c) 6 (d) 4

(iii) The result of the curl of a vector field is
(a) a vector
(b) a scalar
(c) may be a vector or a scalar depending on the field
(d) always zero

(iv) $P = \int_V \overline{E}.\overline{J}\, dV$ is known as:
(a) Gauss's law (b) Ohm's law
(c) Joule's law (d) Continuity equation

(v) The equation $\overline{J} = \sigma\overline{E}$ is known as:
(a) Ohm's Law (b) Gauss's Law
(c) Joule's Law (d) Faraday's Law

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

(vii) For two conductors carrying current in opposite direction, the force between them is
(a) attractive (b) repulsive
(c) no force (d) All of these

(viii) A circular coil of radius 2m carries a current of 4 A. The value of magnetic field intensity at the centre is

(a) 1 A/m (b) 0.2 A/m (c) 0.5 A/m (d) 0 A/m

(ix) The intrinsic impedance η=

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

(x) Which one of the following statements is true?

(a) In lossless dielectric $\overline{\mathrm{E}}$ and $\overline{\mathrm{H}}$ are in time phase with each other

(b) In lossless dielectric $\overline{\mathrm{E}}$ leads $\overline{\mathrm{H}}$ by 90°

(c) In good conductors $\overline{\mathrm{E}}$ leads $\overline{\mathrm{H}}$ by 90°

(d) In good conductors $\overline{\mathrm{E}}$ and $\overline{\mathrm{H}}$ are in time phase with each other

Fill in the blanks with the correct word

(xi) The unit of magnetic field intensity is given by _________.

(xii) The magnetic vector potential is a _________ field.

(xiii) The Lorentz equation is given by _________.

(xiv) The expression of gradient of a scalar V (∇V)in Cartesian coordinates is ___________.

(xv) An example of a vector field which is solenoidal as well as roational __________.

Group - B

2. (a) Write the expressions of differential length in Cartesian, cylindrical and spherical coordinates. *[(CO1)(Understand/LOCQ)]*

(b) Convert the given rectangular coordinates A(8,6,4) into corresponding cylindrical coordinates. *[(CO1)(Evaluate/HOCQ)]*

(c) Examine divergence theorem for the following field:
$\overline{\mathrm{A}} = (\mathrm{x}^3 - \mathrm{yz})\hat{\mathrm{a}}_\mathrm{x} + (\mathrm{y}^3 - \mathrm{zx})\hat{\mathrm{a}}_\mathrm{y} + (\mathrm{z}^3 - \mathrm{xy})\hat{\mathrm{a}}_\mathrm{z}$ for a region defined by $0 \le \mathrm{x} \le \mathrm{a}$, $0 \le \mathrm{y} \le \mathrm{b}$, $0 \le \mathrm{z} \le \mathrm{c}$. *[(CO2)(Analyze/IOCQ)]*

3 + 3 + 6 = 12

3. (a) Convert the rectangular coordinates (−6,9,0) to cylindrical coordinates. *[(CO1)(Evaluate/HOCQ)]*

(b) Convert the rectangular coordinates (0,6,4) to spherical coordinates. *[(CO1)(Evaluate/HOCQ)]*

(c) Determine the gradient of a function $\mathrm{V} = \mathrm{x}^2 + \mathrm{y}^3 + \mathrm{z}^3$ at the point (4, 2, 3). *[(CO2)(Analyze/IOCQ)]*

(d) Find Gradient of a function $\mathrm{V} = \rho^2 \mathrm{z}^2 \sin 3\phi$. *[(CO2)(Apply/IOCQ)]*

3 + 3 + 3 + 3 = 12

Group - C

4. (a) Show the derivation of the electric flux density $\vec{\mathrm{D}}$ with the help of Gauss's Law at any point due to infinite line of charge. *[(CO3)(Understand/LOCQ)]*

(b) Develop the expression of electric field due to electric dipole. *[(CO3)(Apply/IOCQ)]*

(c) Assume volume charge density $\rho_v = \rho^2\cos^2\varphi$ pC/m^3 to calculate total charge enclosed by the cylinder of radius $\rho = 2$m, with $-3 \leq z \leq 3$ m. *[(CO3)(Analyze/IOCQ)]*

4 + 5 + 3 = 12

5. (a) Show the derivation of the electric flux density $\vec{D}$ with the help of Gauss's Law at any point due to infinite sheet of charge. *[(CO3)(Understand/LOCQ)]*

(b) Assume $\vec{D} = (4xy^3z^2)\hat{a}_x + (2xy^2z^2)\hat{a}_y + (2xy^2)\hat{a}_z$ pC/m^2 in free space to calculate (i) total electrical flux passing through the surface x=3, $0\leq y \leq 3$, $0\leq z \leq 3$ in a direction away from the origin. (ii) the total charge contained in a sphere of a radius 1mm centered at point P(2,3,4). *[(CO3)(Analyze/IOCQ)]*

(c) Conclude the relationship between $\vec{E}$ and V. The symbols have their usual meaning. *[(CO3)(Evaluate/IOCQ)]*

4 + 5 + 3 = 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 circular loop of radius *a*. Determine the magnetic field intensity at the centre of the loop. *[(CO2)(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) Prove that the flux density at a distance h on a line passing through the centre of circular loop radius a and carrying current I is given by, $B = \frac{\mu_0 Ia^2}{2(a^2+h^2)^{3/2}}$. The loop is in the XY plane and the line is perpendicular to the plane of the loop. *[(CO4)(Evaluate/HOCQ)]*

(b) State Biot-Savart's Law. *[(CO4)(Remember/LOCQ)]*

(c) A toroid has a core of cross-sectional area of 2500 mm^2, mean diameter 250×10^{-6} m and $\mu_r = 1000$. Determine the number of turns to be wound on the core to obtain an inductance of 1 Henry. *[(CO4)(Evaluate/HOCQ)]*

(d) A circular conductor of radius *a* is carrying current *I*. Determine the magnetic field intensity at the centre of the current loop. *[(CO4)(Evaluate/HOCQ)]*

(e) Using Ampere's Law, show that the magnetic field H at a radius r within a copper conductor carrying a current I is given by $H = \frac{I}{2\pi r}$, when $r > r_0$, where the radius of the cylindrical conductor is r_0. Assume the current to be uniformly distributed throughout the conductor's cross-section. *[(CO4)(Evaluate/HOCQ)]*

4 + 2 + 2 + 2 + 2 = 12

Group - E

8. (a) Compare the displacement current density and conduction current density. *[(CO5)(Analyse/IOCQ)]*

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

(c) An electric field is represented by $\overline{E}_z = 10\sin(6\pi 10^7 t - \beta y)\hat{a}_z$ V/m is propagating at a frequency of 300 MHz through a medium having $\mu_r = 1$ and $\varepsilon_r = 80$. Identify the attenuation constant, phase constant, wavelength, intrinsic impedance and corresponding magnetic field. *[(CO6) (Apply/IOCQ)]*

3 + 3 + 6 = 12

9. (a) Develop the solution of the inconsistency in Ampere's law. *[(CO5)(Apply/IOCQ)]*

(b) Calculate the skin depth δ and propagation constant at a frequency 3MHz in aluminium where conductivity = 34 mS/m and $\mu_r = 1$. *[(CO6)(Analyze/IOCQ)]*

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

(d) Assume a steel pipe is constructed of a material for which $\mu_r = 185$ and $\sigma = 4 \times 10^3$S/m. The two radiuses are 6 mm and 8 mm, and the length is 80 m. If the total current carried by the pipe is $3\cos 10^5 \pi t$ ampere, find effective resistance and DC resistance. *[(CO6)(Analyze/IOCQ)]*

6 + 1.5 + 1.5 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	24.48	52.6	22.92