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 x = 1 and y= -1, then the value of *r* in cylindrical coordinate system is
(a) $\sqrt{2}$ (b) 1 (c) 2 (d) 2.5

(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 divergence of a vector field is
(a) a scalor
(b) a vector
(c) may be a vector or a scalor depending on the field
(d) always zero.

(iv) Electrostatic field $\vec{E} = 0$
(a) inside a perfect conductor (b) inside a dielectric medium
(c) in the air (d) at the boundary of two dielectric

(v) The relationship between $\bar{E}$ and V is
(a) $\bar{E} = -\nabla V$ (b) $\bar{E} = \nabla^2 V$
(c) $\bar{E} = -\nabla^2 V$ (d) $V = -\nabla \bar{E}$

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

(vii) 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

(viii) A thin spherical shell of radius 'a' has a charge +Q evenly distributed over its surface. What will be the electric field inside that shell?
(a) infinite (b) zero (c) $\frac{Q}{4\pi a^2}$ (d) Qa

(ix) Two thin parallel wires carry currents along the same direction the force experienced by one due to the other
(a) parallel to the lines
(b) perpendicular to the lines and attraction
(c) perpendicular to the lines and repulsive
(d) zero

(x) The value of intrinsic impedance for free space is
(a) 0 (b) infinite (c) 1 (d) 377

Fill in the blanks with the correct word

(xi) The energy stored in an inductor or magnetic field is given by _____.

(xii) The coefficient of coupling is given by _____.

(xiii) The unit of scalar magnetic potential is given by _____.

(xiv) The relationship between electric field intensity and electric flux density is _____.

(xv) The speed at which electromagnetic wave travels in the free space _____.

Group - B

2. (a) Write the expressions of converting spherical coordinates into Cartesian coordinates. *[(CO1)(Understand/LOCQ)]]*
(b) Convert the given rectangular coordinates A(6,4,2) into corresponding cylindrical coordinates. *[(CO1)(Evaluate/HOCQ)]*
(c) Categorise vector fields by their divergence and curl. *[(CO2)(Analyze/IOCQ)]*
(d) Determine the Curl of the vector field at (2, 3, 4): $\vec{B} = \hat{a}_x + y^2\hat{a}_y$. *[(CO2)(Analyze/IOCQ)]*

3 + 3 + 4 + 2 = 12

3. (a) Convert the rectangular coordinates (−4,4,0) to cylindrical coordinates. *[(CO1)(Evaluate/HOCQ)]*
(b) Convert the rectangular coordinates (0,−3,4) to spherical coordinates. *[(CO1)(Evaluate/HOCQ)]*
(c) Determine the gradient of a function V= $x^2 + y^3 + z^4$ at the point (4, 2, 3). *[(CO2)(Analyze/IOCQ)]*
(d) Find Gradient of a function V= $\rho^2 z \sin 3\phi$. *[(CO2)(Apply/IOCQ)]*

3 + 3 + 3 + 3 = 12

Group - C

4. (a) How $P = I^2R$ can be derived from $V = \int_L \bar{E}.d\bar{l}$ and $I = \int_S \bar{J}.d\bar{s}$? *[(CO3)(Remember/LOCQ)]*
(b) Develop boundary conditions of electric field for conductor-free space boundary. *[(CO3) (Apply/IOCQ)]*
(c) Assume a homogeneous dielectric $\varepsilon_{r1} = 4$ fills region 1 ($x \leq 0$)while region 2 ($x \geq 0$)is free space. If $\overrightarrow{D_1} = 12\hat{a}_x - 6\hat{a}_y + 7\hat{a}_z$ nC/m2 determine $\overrightarrow{D_2}$. *[(CO3)(Analyze/IOCQ)]*

4 + 5 + 3 = 12

5. (a) Disprove : a perfect conductor can contain an electrostatic field within it. *[(CO3)(Evaluate/HOCQ)]*

(b) Develop boundary conditions of electric field for dielectric-dielectric boundary. *[(CO3)(Apply/IOCQ)]*

(c) Let $\vec{E} = 2\hat{a}_x + 6\hat{a}_y - 7\hat{a}_z$ kV/m exists at conductor- free space boundary. Find and show (i) $|\vec{E}|$ (ii)E_N (iii) E_T (iv) surface charge density ρ_s. *[(CO3)(Understand/LOCQ)]*

4 + 5 + 3 = 12

Group - D

6. (a) Two coils of inductance 4 H and 6 H are connected in series. If their mutual inductance is 3 H, determine the equivalent inductance of the combination if mutual inductance opposes the self inductance. *[(CO4)(Evaluate/HOCQ)]*

(b) Deduce the expression of energy stored in Inductor. *[(CO4)(Analyse/IOCQ)]*

(c) State two similarities and two differences between electric and magnetic circuits. *[(CO4)(Understand /LOCQ)]*

(d) Write the boundary conditions for Magnetic Field. *[(CO4)(Remember/LOCQ)]*

(e) Write the expression of Force between two current carrying conductors. *[(CO4)(Remember/LOCQ)]*

2 + 3 + (2 + 2) + 2 + 1 = 12

7. (a) Derive the expression of force between two current carrying conductors. *[(CO4)(Evaluate/HOCQ)]*

(b) Classify the different types of magnetic materials. *[(CO4)(Analyse/IOCQ)]*

(c) Two long parallel conductors carry 100 A. If the conductors are separated by 20 mm. Determine the force per metre of each conductor if the current flow is in opposite direction. *[(CO4)(Evaluate/HOCQ)]*

(d) A single phase circuit comprises two parallel conductors A and B 1 cm diameter and spaced 1 metre apart. The conductors carry currents of +100A and -100 A respectively. Determine the field intensity at the surface of each conductor and also in the space exactly midway between A and B. *[(CO4)(Evaluate/HOCQ)]*

4 + 3 + 2 + 3 = 12

Group - E

8. (a) What are the Maxwell's equations in integral form? *[(CO5)(Remember/LOCQ)]*

(b) Determine the conduction and displacement current densities in a material having conductivity of 2.5 S/m and $\varepsilon_r = 2$ if the electric field in the material is $E = 150Sin(10^{10}t)$ V/m. *[(CO5)(Evaluate/HOCQ)]*

(c) Identify the attenuation constant, phase constant, propagation constant, wavelength, skin depth and velocity of $\vec{E} = (28e^{-0.06x}Cos(4 \times 10^8 t - 4x)\hat{a}_z$ V/m. *[(CO6)(Apply/IOCQ)]*

3 + 3 + 6 = 12

9. (a) How is Maxwell's third equation in differential form derived from Faraday's Law? *[(CO5)(Remember/LOCQ)]*

(b) A straight conductor of 0.3 m lies on the x axis with one end at the origin. The conductor is subjected to a magnetic flux density $\vec{B} = 0.04\,\hat{a}_y$ Tesla and velocity

$\vec{u} = 4\text{Sin}10^3\text{t}\,\hat{a}_z\ m/s$. Determine the motional electric field intensity and emf induced in the conductor. *[(CO5)(Evaluate/HOCQ)]*

(c) Identify the attenuation constant, phase constant, wavelength, intrinsic impedance and corresponding magnetic field while an electric field is represented by $\overline{E}_y = 20\ \text{Cos}(3\pi 10^8\text{t} - \beta x)\hat{a}_y$ V/m is propagating at a frequency of 250 MHz through a medium having $\mu_r = 1$ and $\varepsilon_r = 75$. *[(CO6)(Apply/IOCQ)]*

3 + 3 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	23.96	44.79	31.25