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) Which relation is not true:
(a) $\nabla(V + U) = \nabla V + \nabla U$ (b) $\nabla(VU) = V\nabla U + U\nabla V$
(c) $\nabla \times (\overline{A} + \overline{B}) = \nabla \times \overline{A} + \nabla \times \overline{B}$ (d) $\nabla.(\nabla \times \overline{A}) = \nabla.\overline{A}$

(ii) Magnetic fields within a current carrying conductor is example of
(a) solenoidal and irrotational vector fields
(b) non-solenoidal and irrotational vector fields
(c) solenoidal and rotational vector fields
(d) non-solenoidal and rotational vector fields

(iii) Point form of Ohm's law is
(a) J=Σe (b) E=σJ
(c) R=VI (d) $\nabla \times E = 0$

(iv) Which is not an example of convection current?
(a) a moving charged belt
(b) electronic movement in a vacuum tube
(c) an electron beam in a television tube
(c) electric current flowing in a copper wire

(v) A scalar field V is said to be harmonic in a given region if in that region
(a) ∇V=0 (b) ∇×V =0
(c) $\nabla^2 V=0$ (d) ∇×∇×V=0

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

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

(viii) At f=2GHz a material has σ=25 S/m. ε_r=80. At this frequency the material act as
(a) Insulator (b) Conductor
(c) Perfect dielectric (d) None of the above

(ix) For time varying fields $\nabla \cdot B$=
(a) P_v (b) Zero
(c) D (d) μJ

(x) In a good conductor the angle between E and H is
(a) 0^0 (b) 90^0
(c) 45^0 (d) depends on medium.

Group – B

2. (a) Transform a Cartesian vector $\overline{A} = 20\,\hat{a}_x - 9\,\hat{a}_y - 6\,\hat{a}_z$ to spherical coordinates at point P (11,150^0,230^0).

(b) Express the vector $\overline{A} = y\,\hat{a}_x - x\,\hat{a}_y$ in cylindrical system.

(c) Convert the point P(-3,-5,-8) into spherical coordinates.

5 + 5 + 2 = 12

3. (a) Prove Stokes's theorem for the path shown in the following Figure.1 and the given vector field :

$$\vec{F} = (y - z + 2)\hat{a}_x + (yz + 4)\hat{a}_y - xz\,\hat{a}_z$$

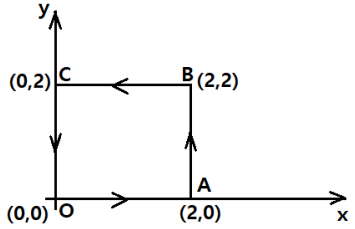

Fig. 1

(b) Determine Laplacian of the scalar field : $V = 2x^3y^2z^4$.

(c) Find Gradient of a function V= $\rho^2 z \sin 3\phi$.

(d) Examine whether the field $\vec{A} = (x - 3y)\hat{a}_x + (y - 5z)\hat{a}_y + (3 - 6z)\,\hat{a}_z$ is solenoidal or not.

6 + 2 + 2 + 2 = 12

Group – C

4. (a) Potential distribution in a given region of free space is of the form $V = 10y^3 + 20x^2 + 5z^2$, obtain $\overline{E}$ at (5,4,7).

(b) Explain physically and mathematically why a perfect conductor cannot contain electrostatic field within it?

(c) Calculate 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 : $\vec{D} = z\rho Cos\phi\ \hat{a_z}$ C/m².

(d) A thin spherical shell of radius 'r' has a charge +Q evenly distributed over its surface. Find the electric field outside the shell.

3 + 3 + 3 + 3 = 12

5. (a) An electric field strength of 1000 V/m in a medium of $\varepsilon_r = 6$ passes into air ($\varepsilon_r = 1$) at an angle of 45° to the normal of boundary. Determine the magnitude of $\bar{E}$ in air.

(b) What is polarization in dielectric ?

(c) The region $z < 0$ contains a perfect dielectric for which $\varepsilon_{r1} = 2.5$ while region $z > 0$ is characterised by $\varepsilon_{r2} = 4$. Assume $\overrightarrow{E_1} = 80\hat{a}_x - 60\hat{a}_y + 30\hat{a}_z$ V/m exist for z<0. Find $\bar{D}_2$.

(d) Develop the continuity equation.

4 + 2 + 4 + 2 = 12

Group – D

6. (a) Find the magnetic field intensity at the centre of a regular hexagon of each side 2cm carrying current 5A.

(b) A solenoid of length 'L' and radius 'r' consist of N turns of wire carrying current 'I'. Find the expression of magnetic field intensity at the axis of the solenoid if L>>r. Also find the inductance of the solenoid.

(c) Find the mutual inductance between a straight long wire carrying current I in positive y-direction and a square loop wire in the same plane of length $'a'$ and breadth $'b'$ and is separated by $'\rho_o'$ as shown in Fig. 2.

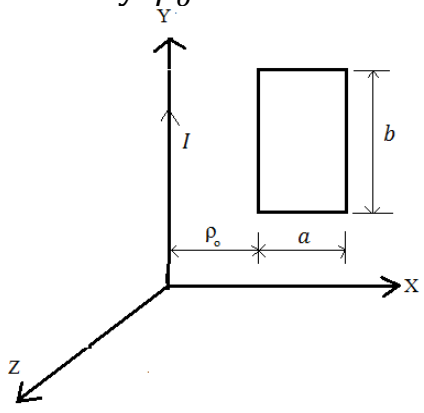

Fig. 2.

(d) What is the physical significance of $\nabla . \bar{B} = 0$.

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

7. (a) A squre core of each side 40 cm in length has cross section 30 cm² with $\mu_r = 1500$ determine the number of turns necessary to get a 3H inductor.

(b) Given that $\vec{H}_1 = -4\hat{a}_x + 8\hat{a}_y - 4\hat{a}_z$ A/m in region $y - 2x - 4 \leq 0$, where $\mu_1 = 6\mu_0$. Calculate $\vec{H}_2$ in region $y - 2x - 4 \geq 0$, where $\mu_2 = 3\mu_0$.

(c) In a certain conducting medium, $\vec{H} = \rho^2\hat{a}_\varphi$ Find J at (1,0,-3).

(d) A conductor AB carrying current I_2 is placed perpendicular to an infinitely long filamentary wire carrying current I_1 as shown in Figure. 3. Find the force experienced by the conductor AB.

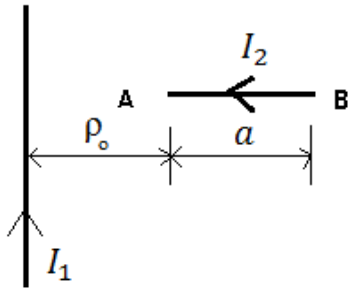

Fig. 3

3 + 4 + 3 + 2 = 12

Group – E

8. (a) What is inconsistency in Ampere's law? How it is rectified by Maxwell?

(b) The electric field of a TV broadcast signal propagating in air is given by $E(z,t) = 0.2\cos(\omega t - 6.5z)\hat{a}_x$ V/m. Find

(i) the wave frequency ω

(ii) the corresponding H(z,t).

(c) In a non magnetic medium $E = 8\sin(2\pi \times 10^7 t - 0.9x)\hat{a}_z$ V/m Find ε_r, η.

(2 + 2) + 4 + 4 = 12

9. (a) For silver, $\sigma = 6.1\times10^7$ S/m, $\mu_r = 1$, $\varepsilon_r = 1$, determine the frequency at which the penetration depth is 2mm.

(b) State and proof Poynting's Theorem'.

(c) Prove that in lossless dielectrics the $\vec{E}$ and $\vec{H}$ of the plane wave are in time phase with each other.

(d) Determine the ac resistance of a round copper wire ($\sigma = 3.5\times10^7$S/m, $\mu_r = 1, \varepsilon_r = 1$) of radius 1.5 mm and length 500m at 15 GHz.

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

Department & Section	Submission Link
EE	https://classroom.google.com/c/MzIxNjk3MzQzNzgw/a/MzYwMDQ2MDU5Mzcw/details