

II B.Tech I Semester Supplementary Examinations, February 2008
ELECTROMAGNETIC FIELDS
 (Common to Electrical & Electronic Engineering and Electronics & Control Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

1. (a) Define the term: “potential difference $V(A) - V(B)$ between points A and B in a static electric field”. Give an energy interpretation to potential difference.
 (b) What are the equipotential surfaces for an infinite straight line of uniform charge density? Explain.
 (c) Potential for a certain region is given by $V(x, y, z) = \frac{300}{x}$ volts; where x is in meters. Find the electric field at the point P: $(x = 1 \text{ m})$. [6+6+4]
2. (a) A conducting body is in the electric field of static charges. Explain why the net electric field at any point inside the conducting body will be zero.
 (b) Use the result of (a) to show that
 - i. the net volume charge density at any point inside the conductor is zero, and
 - ii. the conductor is an equipotential body. [8+4+4]
3. (a) A certain volume of dielectric has a polarization $\bar{P} \text{ C/m}^2$. Write the integral expression for the potential at any point due to this dielectric. Explain the different terms in this expression through a figure,
 (b) A spherical dielectric shell has its center at origin, and its internal and external radii are 49 cm and 50 cm respectively. The shell has a polarization of $3a_r \text{ nC/m}^2$ (spherical coordinates). Considering only the bound surface density on the outer surface, find the potential of the dielectric shell. [8+8]
4. (a) State Biot - Savart's law for the magnetic field $\bar{B}$ due to a steady line current in free space.
 (b) Find $\bar{B}$ due to a straight conductor length $\ell \text{ m}$ and steady current $I \text{ A}$ at a distance of $y \text{ m}$ from the center of the line current. [6+10]
5. If the magnetic field intensity is $H = x^2 a_x + 2yz a_y + (-x^2) a_z$, A/m. Find the current density at point
 - (a) 2, 3, 4
 - (b) $\rho = 6$, $\varphi = 45^\circ$, $z = 3$
 - (c) $r = 3.6$, $\theta = 60^\circ$, $\varphi = 90^\circ$. [4+6+6]
6. (a) With the help of basic definitions, prove that $T = m \times B$

- (b) Filamentary currents of $-25\mathbf{a}_z$ and $25\mathbf{a}_z$ Amp are located in the $x = 0$ plane in free space at $y = -1$ and $y = 1$ m respectively. A third filamentary current of $10^{-3}\mathbf{a}_z$ Amp is located at $x = k$, $y = 0$. Find the vector force on a 1 m length of 1 mA filament. [8+8]
7. If $\mathbf{A} = 10\rho^{1.5}\mathbf{a}_z$ Wb/m in free space, find $\mathbf{H}$, $\mathbf{J}$. [16]
8. (a) Explain how the displacement current density differs from Conduction current density.
- (b) Find the $\mathbf{J}_D$ in air within a larger power distribution transformer where $\mathbf{B} = 1.1 \cos [1.257 * 10^{-6}(3*10^8t - y)] \mathbf{a}_x$ Tesla. [6+10]

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1. (a) State and explain Coulomb's law for the vector force between two point charges in free space.
 (b) A straight line of length ℓ m in free space has a uniform charge density of λ C/m. P is a point on the perpendicular bisector of the line charge, at a distance y m from the line. Find the electric field at P. [6+10]
2. (a) In electrostatics, what is meant by a physical dipole?
 (b) For a physical dipole in the z-direction, located at the origin in free space, find the potential at a point $(r, \theta, \phi = \frac{\pi}{2})$ (in spherical co ordinates).
 (c) Point charges of $1 \mu\text{C}$ and $-1 \mu\text{C}$ are located at $(0,0,1)$ m and $(0,0,-1)$ m respectively in free space.
 i. Find the potential at $(0,3,4)$ m.
 ii. Recalculate the same potential, treating the dipole as a pure dipole. [6+6+4]
3. (a) A certain volume of dielectric has a polarization $\bar{P}$ C/m². Write the integral expression for the potential at any point due to this dielectric. Explain the different terms in this expression through a figure,
 (b) A spherical dielectric shell has its center at origin, and its internal and external radii are 49 cm and 50 cm respectively. The shell has a polarization of $3a_r$ nC/m² (spherical coordinates). Considering only the bound surface density on the outer surface, find the potential of the dielectric shell. [8+8]
4. (a) State Biot-Savart's law for the field $\bar{B}$ due to a steady line current in free space.
 (b) Find the magnetic field $\bar{B}$ at the center of the axis of a solenoid of radius R m, axial length ℓ m, and N turns per meter closely wound, which is carrying a steady current I A.
 (Hint: In figure 4b, magnetic field $\bar{B}$ at $P = \frac{\mu_0 I r^2}{2(r^2+z^2)^{3/2}} a_z$ T). [4+12]

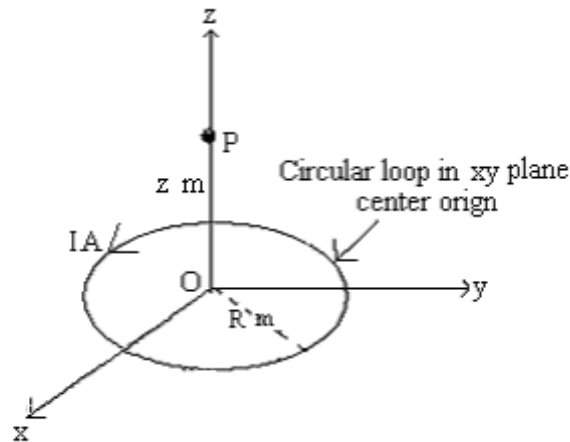


Figure 4b

5. (a) What are the limitations of Amperes current law? How this law can be modified to time varying field.
- (b) A circular loop located on $x^2 + y^2 = 9$, $z = 0$ carries a direct current of 10 A. along a_φ direction. Determine H at (0, 0, 5) and (0, 0, -5). [8+8]
6. (a) Justify the statement 'Most of the electrical machines are working on electromagnetic principles rather than the electrostatic principles'
- (b) A galvanometer has a rectangular coil side of 10 mm * 30 mm pivoted about the center of shorter side. It is mounted in a radial magnetic field so that a constant magnetic field of 0.4 T always acts across the plane of the coil. If the coil has 1000 turns and carries current 2 mA, find the torque exerted on it. [8+8]
7. (a) Explain the Laplace's & Poisson's' equations for steady magnetic field.
- (b) A current sheet $K = 2.4 a_z$ A/m is present at the surface $\rho = 1.2$ in free space. Find H for $\rho > 1.2$. Find scalar magnetic potential at (1.5, 0.6π , 1), if scalar magnetic potential is zero at $\varphi = 0$ and barrier is at $\varphi = \pi$. [8+8]
8. (a) Obtain the expression for Displacement current density.
- (b) Find the displacement current density next to your radio, in air, where the local FM station provides a carrier having $H = 0.2 \cos [2\pi(3 * 10^8 t - x)] a_z$ A/m. [8+8]

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1. (a) Discuss the term “electric field due to a static charge configuration”.
- (b) Find the electric field at a point outside a sphere of radius R m in free space which carries a uniform charge density ρ C/m³. Use Gauss’s law.
- (c) 4 point charges of $500 \mu\text{C}$ each are placed at the corners of a square of $3\sqrt{2}$ m side. The square is located in the $z = 0$ plane between $x = \pm \frac{3}{\sqrt{2}}$ m and $y = \pm \frac{3}{\sqrt{2}}$ m in free space. Find the force on a point charge of $30 \mu\text{C}$ at $(0,0,4)$ m. [6+6+4]
2. (a) Show that the torque on a physical dipole $\vec{p}$ in a uniform electric field $\vec{E}$ is given by $\vec{p} \times \vec{E}$. Extend this result to a pure dipole.
- (b) Two pure dipoles $\vec{p}_1$ and $\vec{p}_2$ are located in free space as shown in the figure 2b. Find the torque on $\vec{p}_2$ due to the field of $\vec{p}_1$. [It is given that the electric field $\vec{E}(r, \theta, \phi)$ due to a pure dipole $p_a z$ at the origin is $\frac{P}{4\pi\epsilon_0 r^3} (2 \cos \theta a_r + \sin \theta a_\theta)$ in spherical coordinates]. In which direction will $\vec{p}_2$ tend to rotate due to this torque? [10+6]

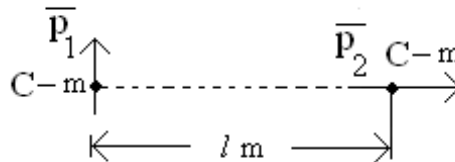


Figure 2b

3. (a) Establish the electrostatic boundary conditions for the tangential components of electric field and electric displacement at the boundary of two linear dielectrics.
- (b) $z < 0$ is a region of a linear dielectric of relative permittivity 6.5; and $z > 0$ is free space. Electric field in the free space region is $(-3a_x + 4a_y - 2a_z)$ V/m. Find
 - i. $\vec{D}$ for $z > 0$;
 - ii. tangential components of $\vec{D}$ & $\vec{E}$ for $z < 0$, on the boundary. [8+8]
4. (a) i. A steady current element $10^{-3}a_z$ A-m is located at the origin in free space. What is the magnetic field $\vec{B}$ due to this element at the point $(1,0,0)$ m (in rectangular coordinates)?

- ii. What is the magnetic field at the point (0,0,1) m?
- (b) Find $\vec{B}$ due to a straight length ℓ m of steady current I A at a distance of y m from the center of the line current. [6+10]
5. Evaluate both sides of Stoke's theorem for the field $H = \frac{y^2 z}{x} a_x + \frac{0.5 y^2 z^2}{x^2} a_z$ A/m and find the current in a_y direction crossing the square surface in the plane $y = 2$ bounded by $x = z = 1$ and $x = z = 2$. [16]
6. In region 1, where $r \cdot (2a_x - 3a_y + a_z) > 5$, let $\mu_{r1} = 10$ and in region 2 where $r \cdot (2a_x - 3a_y + a_z) < 5$, let $\mu_{r2} = 2$. $B_1 = 10a_x + 20a_y + 30a_z$ mT everywhere in region 1.
- (a) Find the angle θ_1 that B_1 makes with the unit normal a_{N21} .
- (b) Find the angle θ_2 that B_2 makes with the unit normal a_{N21} . [8+8]
7. (a) Obtain the expression for inductance of a toroid.
- (b) A solenoid of 10 cm in length consists of 1000 turns having the cross section radius of 1 cm. Find the inductance of solenoid. What is the value of current required to maintain a flux of 1 mWb in the toroid. Take $\mu_r = 1500$. [8+8]
8. (a) Obtain the expression for Displacement current density.
- (b) Find the displacement current density next to your radio, in air, where the local FM station provides a carrier having $H = 0.2 \cos [210(3 \cdot 10^8 t - x)] a_z$ A/m. [8+8]

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1. (a) $\vec{E}$ is the electric field due to a point charge Q C at the origin in free space. Find $\oint_S \vec{E} \cdot d\vec{a}$ where S is a spherical surface of radius R m and center at origin.
 (b) Using Gauss's law, show that the electric field due to an infinite straight line of uniform charge density λ C/m along the z -axis in free space is $(\lambda/2\pi\epsilon_0 r) a_r$ N/C.
 (c) An infinitely long cylinder of radius 1m in free space is filled with a uniform charge density of 1nC/m^3 . If the potential on the axis of the cylinder is 100 V, find the potential variation inside the cylinder. [6+6+4]
2. (a) A conducting body is in the electric field of static charges. Explain why the net electric field at any point inside the conducting body will be zero.
 (b) Use the result of (a) to show that
 - i. the net volume charge density at any point inside the conductor is zero, and
 - ii. the conductor is an equipotential body. [8+4+4]
3. (a) A certain volume of dielectric has a polarization $\vec{P}$ C/m². Write the integral expression for the potential at any point due to this dielectric. Explain the different terms in this expression through a figure,
 (b) A spherical dielectric shell has its center at origin, and its internal and external radii are 49 cm and 50 cm respectively. The shell has a polarization of $3a_r$ nC/m² (spherical coordinates). Considering only the bound surface density on the outer surface, find the potential of the dielectric shell. [8+8]
4. (a) A steady current of I A extends along the z -axis from $-\frac{\ell}{2}$ m to $\frac{\ell}{2}$ m in free space. Find the magnetic field $\vec{B}$ at a point on the y -axis y m from the origin, using Biot-Savart's law.
 (b) Extend the result of (a) to an infinite straight line of steady current. Express the result in cylindrical co ordinates. [10+6]
5. Obtain the expression for the magnetic field intensity and sketch the same for a co-axial cable. [16]
6. (a) Justify the statement 'Most of the electrical machines are working on electromagnetic principles rather than the electrostatic principles'

- (b) A galvanometer has a rectangular coil side of 10 mm * 30 mm pivoted about the center of shorter side. It is mounted in a radial magnetic field so that a constant magnetic field of 0.4 T always acts across the plane of the coil. If the coil has 1000 turns and carries current 2 mA, find the torque exerted on it. [8+8]
7. (a) Obtain the expression for inductance of a toroid.
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8. (a) Explain the terms
- i. Motional EMF
 - ii. Static EMF
- (b) A copper wire carries a conduction current of 1 Amp. Determine the displacement current in the wire at 1 MHz. for copper $\varepsilon = \varepsilon_0$ and $\sigma = 5.8 * 10^7$ Siemens/m. [8+8]
